

The AMSAT Journal

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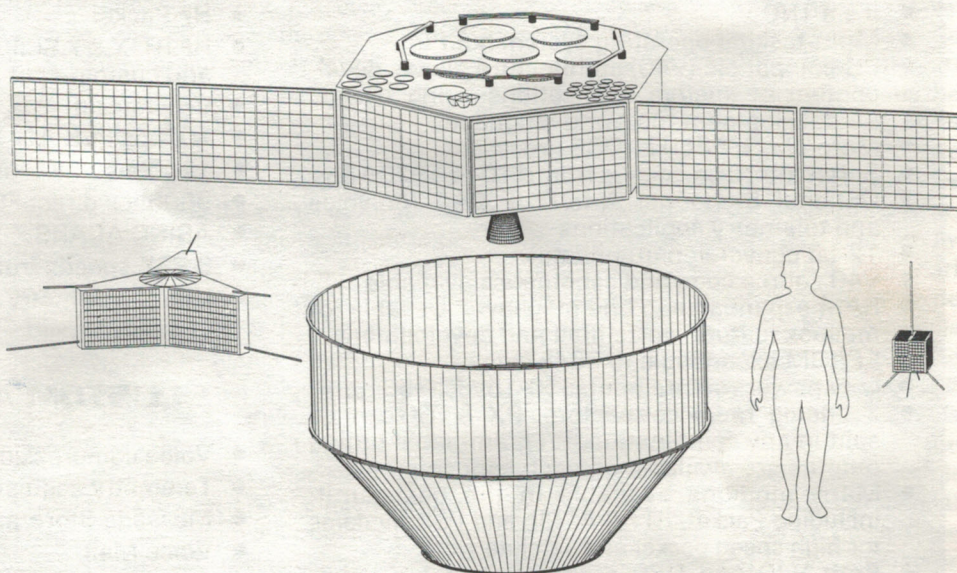
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New Agreement with the European Space Agency on Phase 3D Design

By: Dick Jansson, WD4FAB
AMSAT-NA V.P. of Engineering



AMSAT-NA Vice President for Engineering Dick Jansson, WD4FAB enthusiastically announces a major milestone in the Phase 3D project.

As was stated in November, the European Space Agency (ESA) informed us at a meeting in Europe, that it would not provide the interface which Phase 3D had been designed to over the past two years. This involved a conical section tapering from approximately 1920 mm (about 6.3 ft.) to approximately 1200

mm (about 4 ft.) in diameter. This conical section was to be the central structural core of the Phase 3D satellite.

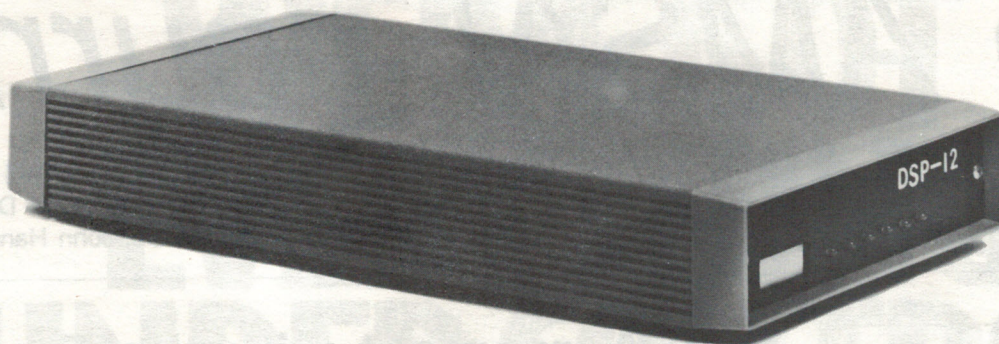
What ESA offered instead was a cylindrical section 2624 mm (8.6 ft.) in diameter and 750 mm (approximately 2.5 feet) high, coupled with a 860 mm (approximately 34 in.) high conical section, which tapers to 1200 mm. This led WD4FAB to conduct an exhaustive

(continued on page 6)

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Phase 3D Project Continues!

By: Bill Tynan, W3XO
President AMSAT-NA

You have perhaps heard of the change in the Phase 3D interface recently announced by the European Space Agency (ESA). Various stories and rumors have circulated that it represents a major setback for Phase 3D, perhaps even a life threatening one. As Dick Daniels wrote in his report on the situation in the last Journal, this is definitely not the case. In fact, like many occurrences, the ESA announcement carries with it several advantages for us.

At the expense of repeating some of the things Dick said in the past issue, I will attempt to summarize what happened and explain what it means in terms of a setback as well as some of the advantages it affords.

First, I find it more than a little reassuring that an ESA official journeyed to Marburg while Dick Jansson WD4FAB was there conferring with Karl Meinzer last November, rather than waiting for Karl and Dick to visit ESA headquarters in Paris which they were scheduled to do. What the official told them was that ESA had found no commercial interest for satellites that would employ the specific interface they had previously indicated would be provided for Phase 3D. This consisted of a ring 1920 millimeters (about 6.3 feet) at the bottom, tapering to a smaller 1194 millimeter (just under 4 feet) ring at the top. This conical section, which the amateur community would supply, was to support other satellites mounted on the smaller circle. The mechanical design concept that has been pursued to date involved using this conical section as the central structure of the Phase 3D spacecraft. The electronic boxes, and structure to support solar arrays and heat radiators were to be built around the central core, with propulsion systems inside it. A great deal of design work has been done in support of this design concept and several models have been constructed - one full scale.

In addition, because of the critical nature of this conical adaptor (It had to carry the weight of the satellites mounted above it during launch.), work has already been done to fabricate qualification and flight units. This involved the forging of several massive aluminum rings costing approximately \$17,000.

That's the bad news - a lot of design time, the construction of several models and the expenditure of a substantial sum of money. The good news is that we are about to get a solid agreement with ESA on a new interface - one consisting of a cylindrical structure in place of the conical one. This should be much easier to analyze and potentially less difficult to fabricate. I say potentially because the new interface circle is much larger, 2624 millimeters (8.6 feet) in diameter. This large size will require the use of more massive fabrication facilities than the former conical shape. We still have to provide it. However, the larger cylinder offers much more space for equipment. The concept presently being pursued by Dick Jansson, Dick Daniels and Karl Meinzer calls for a satellite carried inside the large cylinder and which separates from it following its detachment from the Ariane launch vehicle; rather than using it as the central core of the satellite. This affords several advantages. First; the satellite can be considerably lighter, so it requires less propellant to get to its final orbit. In addition; it can be much more regular in shape and hence should be easier to construct and handle.

Most importantly, the change in spacecraft configuration will have absolutely no effect on its internal electronics modules and more importantly, what it does for us amateurs. The final orbit parameters are unaffected. It will still be three axis stabilized, so that its high gain antennas always point toward earth. If anything, more space appears to be available for antennas than with the old design. Reports from Dick Jansson indicate that Stan Wood, WA4NFY has come up with a very promising 2 meter antenna design. (Yes, Mode B still lives.)

So, the new interface offered by ESA does NOT mean the end of Phase 3D. It does mean that some expensive material will probably have to be scrapped and that a great deal more mechanical and thermal design work will have to be accomplished. But, Dick Jansson has a good start on this.

Rest assured. Our commitment to Phase 3D remains firm and work on it continues.

(continued on page 19)

Another Banner Year Planned for the Shuttle Amateur Radio Experiment (SAREX)

By: Frank H. Bauer, KA3HDO
AMSAT V.P. for Manned Space Programs
E-Mail: ka3hdo@amsat.org

The Shuttle Amateur Radio Experiment (SAREX) team has been working diligently behind the scenes to provide another "frequent flyer" year for SAREX operations. Currently, three SAREX missions are manifested to be flown in 1993. In addition, there is a distinct possibility that two additional flights may be manifested later in the year. If this occurs, we will have five SAREX flights this year!

Three back-to-back SAREX missions are currently slated in 1993. These include the STS-55 space shuttle Columbia flight which will carry the German Spacelab module into orbit, the STS-56 shuttle Discovery flight carrying the Atmospheric Laboratory for Applications and Sciences (ATLAS-2) spacelab payload and the STS-57 shuttle Endeavour flight which will carry the new spacehab module. Table 1 summarizes the three SAREX flights for 1993. STS-55 and STS-57 flights will be in a low (28.5°) inclination orbit. High latitude cities in the U.S. and Europe will have low elevation passes ($< 10^\circ$) for this mission. STS-56 will be in a high (57°) inclination orbit. For this mission, the orbiter flight path will allow high elevation ($> 50^\circ$) passes for all of the continental U.S. and all of Europe.

STS-55 Details

The STS-55 mission is a 9 day mission with a low inclination orbit. This mission is the first spacelab module flight of 1993. It is designated SL-D2 and represents the second in a series of dedicated flights for Germany. The primary goals of this mission are to perform studies in materials and life sciences research.

SAREX configuration C was selected for this mission. Configuration C includes 2-meter FM voice and 2-meter FM packet. Four of the seven STS-55 crew members are licensed. These include Commander Steve Nagel, N5RAW, Payload Commander Jerry Ross, N5SCW, German Payload Specialist Hans Schlegel, DG1KIH, and German Payload Specialist Ulrich Walter, DG1KIM. The primary voice callsign will be N5RAW. The packet radio callsign for this mission (and all missions in 1993) is W5RRR-1. Nine U.S. and five foreign school groups have been selected for direct contacts on this flight. Since this will

be a low inclination orbit, the teleconference bridge will be used for this mission for school contacts.

In addition to the U.S. SAREX ham gear in the Shuttle mid-deck, an additional ham radio station will be flown in the German spacelab module. This station, designated SAFEX (for Spacelab Amateurfunk-Experiment), includes a 2-meter FM downlink and a 70-cm FM uplink capability. A dual band (2-meter/70-cm) external antenna, mounted on the German spacelab module, will be used for SAFEX contacts. Payload Specialists Schlegel and Walter expect to make a few scheduled contacts with European schools with this equipment.

The externally mounted SAFEX antenna gives the SAREX team a unique opportunity to compare the performance of the U.S. SAREX window mounted antenna to an externally mounted antenna. A special antenna test is planned on orbits 61 and 62 using the normal SAREX downlink frequency, 145.55 MHz. During orbit 61 the shuttle crew will transmit using the SAREX window mounted antenna. On orbit 62 the crew will transmit using the externally mounted SAFEX antenna. Members of the Motorola Amateur Radio Club in Florida will conduct extensive field strength measurements during the two passes to evaluate system performance. In addition, individuals in the Southeastern U.S. are welcome to participate in this test by taking signal strength readings of the received signal for both orbit passes in your area. If the shuttle is well above your horizon ($> 10^\circ$) for both passes and antenna obscuration is not a problem at your QTH, we solicit your support. For more details, see page 42 of the February, 1993 QST. In addition, to participate in the test, request a SAREX Antenna Test Report Package from the ARRL Educational Activities Department, ARRL, 225 Main St., Newington, CT 06111. Please include a self-addressed stamped envelope.

STS-56 Information

Ken Cameron, KB5AWP, will be the Commander for the STS-56 shuttle mission which has a planned liftoff of 5:50 UTC on March 23. This rare night launch from the Kennedy Space Center will place the space shuttle

Discovery in a 57° (high inclination) orbit. The Atmospheric Laboratory for Applications and Sciences (ATLAS-2) spacelab payload is the second in a series of missions to measure the long-term variability in the total energy radiated by the Sun and study its interaction with the Earth's atmosphere. The first ATLAS flew on the STS-45 mission in March 1992 (also a SAREX flight). This Spacelab mission uses pallet-mounted hardware in the Shuttle payload bay to study the Earth's atmosphere and variables in the solar spectrum.

Four of the five crew members are currently licensed. The fifth crew member, Steve Oswald, passed his exam and is waiting for his callsign. The five crew members on this mission include Commander Cameron, KB5AWP, Pilot Steve Oswald, Mission Specialist Ken Cockrell, KB5UAH, Mission Specialist Mike Foale, KB5UAC, and Mission Specialist Ellen Ochoa, KB5TZZ. STS-56 will carry SAREX configuration D. Configuration D includes 2-meter FM voice, packet, SSTV and 70 cm ATV (receive only). The primary voice callsign for this mission will be KB5AWP. Since this is a high inclination orbit, direct school contacts will be planned.

STS-57 Details

STS-57 is a 7 day mission with a low (28.5°) inclination orbit. Liftoff is tentatively scheduled for April 28. The primary mission objective is to fly the first Spacehab middeck augmentation module and retrieve the European Retrievable Carrier deployed from Atlantis on the STS-46 mission in August 1992. Shuttle pilot Brian Duffy, who operated SAREX on STS-45 in March of last year, will be the control operator on the Space Shuttle Endeavour flight. Brian Duffy's callsign is N5WQW. STS-57 will fly SAREX in configuration C, 2-meter voice and packet. Since this will be a low inclination orbit, the teleconference bridge will be used on this mission for school contacts. Keplerian elements and additional information on this flight will be provided as the launch time draws near.

SAREX Frequencies

The Shuttle uplink frequencies have changed somewhat since the last SAREX flight. The



STS-55 CREW

Five NASA astronauts and two German payload specialists, assigned to fly aboard the Space Shuttle Columbia in support of the Spacelab D-2 mission, pose for the traditional crew portrait. On the front row, left to right, are Terence T. (Tom) Henricks, pilot; Steven R. Nagel, mission commander; and Charles J. Precourt, mission specialist. In the back are, left to right, Bernard A. Harris Jr., mission specialist; Hans Schlegel, payload specialist; Jerry L. Ross, payload commander; and Ulrich Walter, payload specialist.

Photo Courtesy of NASA

specific frequencies are listed in a separate article in *The AMSAT journal*. Please read this article and follow the frequency plan carefully. As in the past, split Uplink/Downlink frequencies are being used for this mission with a primary, worldwide downlink frequency of 145.55 MHz. The Astronauts will not favor any of the uplink frequencies, so your ability to establish contact with the Shuttle crew will be somewhat the "luck of the draw." Notice that different uplink frequencies have been chosen for Europe and the rest of the World. Please remember that the crew will not be operating in a simplex mode, so **DO NOT TRANSMIT ON THE DOWNLINK FREQUENCY 145.55 MHz!!**

Information Bulletins

Several bulletin stations will be available, some around-the-clock, to provide up-to-the-minute SAREX information. These include the Goddard Space Flight Center ARC, WA3NAN, in Greenbelt Maryland, the Johnson Space Center ARC, W5RRR, in Houston Texas, and the American Radio Relay League Station, W1AW in Newington Connecticut. W1AW will broadcast SAREX bulletins as part of its normal daily bulletin service. See the QST magazine for more details on frequencies and bulletin schedules. WA3NAN plans to operate around the clock during the entire mission, providing Keplerian Elements, SAREX operating schedules, frequency reminders, and other general SAREX information. In addition, WA3NAN will broadcast Live Space Shuttle air-to-ground audio throughout the mission. WA3NAN

plans to use the following frequencies: 3860 kHz, 7185 kHz, 14,295 kHz, 21,395 kHz and 28,650 kHz on H.F. and on 147.45 MHz on VHF in the Washington D.C. area. W5RRR will provide news bulletins and answer questions on HF when operators are available. W5RRR plans to use the following frequencies: 3850 kHz, 7227 kHz, 14,280 kHz, 21,350 kHz and 28,400 kHz on H.F. and on 146.64 MHz on VHF in the Houston Texas area. In addition to the above sources, information will be disseminated world-wide via packet and on internet using amsat.org.

Keplerian Elements

During the mission, orbit parameters can be obtained via packet radio, via internet (on amsat.org), through the Goddard Amateur Radio Club's Shuttle Retransmissions, through bulletins from the ARRL's W1AW station, and via the JSC Radio Club Station, W5RRR. Table 2 represents the pre-launch Keplerian elements for the STS-55 mission and Table 3 represents the pre-launch Keplerian elements for the STS-56 mission. These have been generated by Gil Carman, WA5NOM from the JSC ARC. If you do not have a satellite/Shuttle orbit tracking program, AMSAT sells a number of these programs for various computer systems. Contact AMSAT Headquarters at 301-589-6062.

QSLs

As with all SAREX flights, a special QSL card is planned for each SAREX mission. If you make a 2-way contact with the crew or

hear the SAREX downlink, you qualify for a QSL card for that mission.

The IBM Amateur Radio Club of Boca Raton Florida has volunteered to act as the QSL manager for the STS-55 SAREX mission. For the STS-55 mission, please send your QSLs to:

IBM Amateur Radio Club/1993
PO Box 1328
Boca Raton, FL 33429-1328

On the outside of the envelope, please write STS-55 SWL or STS-55 QSL—2-Way depending on whether you heard the downlink or made a two-way contact.

For all QSLs, it is essential that you include an SASE using a large (4 inch x 9.5 inch) envelope. If an SASE or sufficient IRCs are not included with your signal report you will not receive a QSL card. Please expect a lengthy (6-10 month) wait after the Shuttle mission to receive your QSL card. This wait is not due to our QSL manager volunteers. The development of a SAREX QSL card can be a very lengthy process. It is nearly one month before mission photos are available to the SAREX team. At this point, the card layout process can begin. Card layout, crew approval, and audio tape logging takes at least 2-3 months, sometimes longer. Card printing and shipment to the QSL manager takes approximately 2 months. In addition, QSL distribution usually takes approximately 2 months. Like other prized DX cards, please be patient for your card to arrive. Each SAREX QSL card has always proven itself to be worth the wait!

A Final Thought

AMSAT always welcomes your comments and suggestions to improve the SAREX program. Please keep in mind that it is not always easy to incorporate all comments or suggestions since this is a volunteer service that is operating within the safety constraints

of the Space Shuttle program and the rules of the IARU and the FCC. Send your comments to me through the AMSAT Headquarters address. Good luck and hope you can make that special contact with the Shuttle Astronauts!■

New Agreement:

(continued from page 1)

series of design studies, including all-important thermal considerations. These pointed to a completely new design concept for Phase 3D, one employing a much smaller spacecraft carried inside the adaptor section and separating from it following its detachment from the Ariane launch vehicle, rather than using it as a central structural core.

It was not known, however, if ESA would support such a concept. But, on January 27, 1993 the answer came. In a meeting between Dr. Karl Meinzer, DJ4ZC and ESA officials, an agreement was reached on the use of the separable configuration.

This means that detailed design of the structural and thermal aspects of the satellite can commence in earnest. WD4FAB is working full-time on the task and expects to have it completed by August.

This new design concept offers several advantages compared to the previous one.

First: Amsat is responsible for the design of only the cylinder and its bolt circles and this is considerably simpler than the conical structure that we had to design under the old concept.

Second: ESA will be responsible for the conical portion of the adaptor section and the separation hardware between the cylindrical portion and the Ariane 5 vehicle.

Third: A new 2300 mm (9 ft.) diameter by 700 mm (27.5 in.) high Phase 3D spacecraft will reside inside the adaptor section. This makes for a significantly lighter satellite than under the previous concept in which the old conical adaptor section formed a part of the spacecraft's structure. This means that much less propellant will be required to get into the final orbit. With the new design approach, P3D is estimated to weigh only about 430 kg (about 950 lbs.) including propellant as apposed to nearly 600 kg (over 1300 lbs.) previously. It should be emphasized that this smaller spacecraft will be just as capable as the old one, in so far as providing amateur communications and supporting various other experiments. It is currently estimated, however, that the solar arrays will produce somewhat less power, about 730 watts compared with 870 watts for the old configuration.

Fourth: The necessary omnidirectional antennas, and most importantly the rocket nozzle, and in fact any other structural elements can protrude up to 400 mm into the conical section. This provides much more design latitude than under the previous approach.

As the program picks up momentum the need for funds grows apace. We invite all to carefully read President Bill Tynan's column in this issue of *The AMSAT Journal* regarding fundraising and the need for everyone to make a five year commitment to the P3D program.■

Table 1 1993 SAREX FLIGHTS					
Mission	Date	Time	Ham Crew	Inclin	Modes
STS-55/SL-D2 Columbia	2/25	9 day	Steve Nagel N5RAW Jerry Ross N5SCW Hans Schlegel DG1KIH Ulrich Walter DG1KIM	28.5	FM Voice Packet
STS-56/ATLAS-2 Discovery	3/23	9 day	Ken Cameron KB5AWP Ken Cockrell KB5UAH Mike Foale KB5UAC Ellen Ochoa KB5TZZ	57	FM Voice Packet SSTV FSTV
STS-57/Spacehab4/28 Endeavour		7 day	Brian Duffy N5WQW	28.5	FM Voice Packet

Table 2 STS-55 element set JSC-002	
Launch: Feb 25 @ 15:20 UTC	
STS-55	
1 00055U 93056.68944922 .00120200 00000-0 36300-3 0 22	
2 00055 28.4697 216.9602 0003812 314.2100 45.8202 15.90487610 23	
Satellite: STS-55	
Catalog number: 00055	
Epoch time: 93056.68944922 ===== (25 FEB 93 16:32:48.41 UTC)	
Element set: JSC-002	
Inclination: 28.4697 deg	
RA of node: 216.9602 deg Space Shuttle Flight STS-55	
Eccentricity: .0003812 Prelaunch Keplerian Elements	
Arg of perigee: 314.2100 deg Launch: 25 FEB 93 15:20 UTC	
Mean anomaly: 45.8202 deg	
Mean motion: 15.90487610 rev/day W5RRR - G. L. Carman	
Decay rate: 1.2020e-03 rev/day ^2 NASA Johnson Space Center	
Epoch rev: 2	

Table 3 STS-56 element set JSC-002	
Launch: Mar 23 @ 5:50 UTC	
STS-56	
1 00056U 93 82.30325346 .00055200 00000-0 16200-3 0 28	
2 00056 57.0020 168.1447 0011289 286.7156 73.2672 15.91759473 24	
Satellite: STS-56	
Catalog number: 00056	
Epoch time: 93082.30325346 ===== (23 MAR 93 07:16:41.10 UTC)	
Element set: JSC-002	
Inclination: 57.0020 deg	
RA of node: 168.1447 deg Space Shuttle Flight STS-56	
Eccentricity: .0011289 Prelaunch Keplerian Elements	
Arg of perigee: 286.7156 deg Launch: 23 MAR 93 05:50 UTC	
Mean anomaly: 73.2672 deg	
Mean motion: 15.91759473 rev/day G. L. Carman	
Decay rate: 5.52000e-04 rev/day ^2 NASA Johnson Space Center	
Epoch rev: 2	

SAREX Frequencies on 1993 Space Shuttle Missions

By: Frank Bauer, KA3HDO

AMSAT V.P. for Manned Space Programs

E-Mail: ka3hdo@amsat.org

The following frequencies will be used for Shuttle Amateur Radio Experiment (SAREX) missions during 1993. These frequencies were chosen after much deliberation to minimize contention between SAREX operations and other 2-meter users. If you have any comments, please direct them to AMSAT via Frank Bauer, KA3HDO (at his callbook address) or to the Educational Activities Department at ARRL Headquarters. We appreciate the cooperation of all amateurs in making the SAREX operations successful.

Most SAREX operations are split-frequency. One frequency is used for "downlink" (the astronauts transmit to Earth stations) and a separate frequency is used for the "uplink" (Earth stations transmit to the astronauts).

SAREX Voice Frequencies

The following frequencies are used for two-way voice communications with the Shuttle astronauts.

Downlink: 145.55 MHz Worldwide

Uplinks

Europe: 144.70, 144.75 and 144.80 MHz

Rest of

world: 144.91, 144.93, 144.95, 144.97 and 144.99 MHz

Note: The crew will not favor any specific uplink frequency, so your ability to communicate with SAREX will be the "luck of the draw."

SAREX Packet Frequencies

The following frequencies are used for packet communications with the Shuttle.

Downlink: 145.55 MHz

Uplink: 144.49 MHz

For all operations, Earth stations should listen to the downlink frequency and transmit only when the Shuttle is in range and the astronauts are on the air. Listen for any instructions from the astronauts as to specific uplink frequencies in use during the current pass. In addition, listen to the uplink frequencies before transmitting to avoid interference to other users.

Note: The first 1993 mission, STS-55, is scheduled to begin February 25. If the mission slips a few days beyond this date, it will coincide with the Phone weekend of the ARRL International DX Contest (March 6-7). Should STS-55 coincide with this contest weekend, Shuttle voice uplinks using the 144.91 to 144.99 MHz range will be curtailed DURING THE ENTIRE MISSION. If this is necessary, SAREX will operate voice using the following frequencies:

Modified SAREX Voice Frequencies

Use only if STS-55 mission coincides with ARRL International DX Contest March 6-7, 1992.

Downlink: 145.55 MHz Worldwide

Uplinks

Europe: 144.70, 144.75 and 144.80 Mz

Rest of world: 144.49, and 144.47 MHz

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Computer Processing of UO-22 and KO-23 Images

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With the launch of KO-23 during the summer of 1992, radio amateurs gained access to a third satellite with Earth imaging capability. UO-22 (launched 1991) and WO-18 (launched 1990) are both operating well and broadcasting images of the Earth. This article will focus on UO-22 and KO-23, so consult the comprehensive article in the December 1992 issue of QST for more information on WO-18.

UO-22 has one camera with a resolution of approximately two kilometers per pixel. KO-23, which is in a higher orbit, has two cameras: a wide-area camera that has a resolution of approximately four kilometers per pixel as well as a narrow-field camera with a resolution of about 400 meters per pixel. Both spacecraft are gravity-gradient stabilized, so the imaging systems usually point straight down. Figure 1 is an example of the images these cameras produce; this UO-22 image is of the Aral Sea in the former Soviet Union.

Other sources of satellite imagery that are familiar to many amateur radio operators are

polar-orbiting weather satellites such as the NOAA and Meteor series. NOAA Automatic Picture Transmission (APT) imagery has a resolution of approximately four kilometers per pixel, about the same as the KO-23 wide-angle camera. While the weather satellites produce excellent images, the images are restricted to the area below the satellite as the data is broadcast in real time. UO-22 and KO-23 are more flexible in that these satellites can acquire and downlink images of any point on the Earth.

Many amateurs have received satellite data and displayed images on computer monitors. There is no reason to stop there now that sophisticated digital image processing techniques are no longer the exclusive domain of space agencies and military forces. The powerful computer hardware necessary for these tasks is readily available—most satellite operators use such a machine for tracking satellites. With the introduction of public-domain software tools for image processing, all the components are in place for an amateur

satellite operator to extract incredible detail from image data files.

Image Acquisition

Downloading an image from UO-22 or KO-23 is much like downloading any other Pacsat file except that the image file is large (over 300 kilobytes). The recently-implemented "thumbnail images" are smaller files that allow users to determine if an image is worth downloading in full. A typical user probably captures the file broadcast for several passes, then uploads hole file requests to complete the file. After extracting from the download file, the user must run utility programs to remove duplicate data buffers, interleave two data fields, and remove the non-image header of the file. The resulting raw image is sometimes called a "raster" file. A user might then use a simple raster file display program to view the unimproved image.

Another way to acquire some images is through terrestrial computer networks. Some satellite users have downloaded images from the satellites, converted the images to GIF files, then uploaded the files to CompuServe or Internet ftp sites. The GIF format is widely used for two reasons: GIF files can be read by most computers and data compression is built into the GIF format. Data compression that can approach 50% certainly helps reduce downloading time. GIF viewing programs automatically show the image at the appropriate resolution for the computer display.

Image Processing

To understand image processing, a user first needs to understand the format of the image data files. The image is essentially a two-dimensional array of 8-bit numbers, where each number represents a shade of gray for the corresponding picture element or "pixel."

With 8 bits per pixel, each can have one of 256 values. Some programs use 0 as black and 255 as white while others reverse this order. The value of 128 corresponds to medium gray, for example.

Perhaps the most common image processing task is stretching contrast (most of the GIF images available for downloading have had contrast stretched). Consider an image of a mountain range during the summer. Without white snow or dark oceans, the image appears on the screen as a seemingly

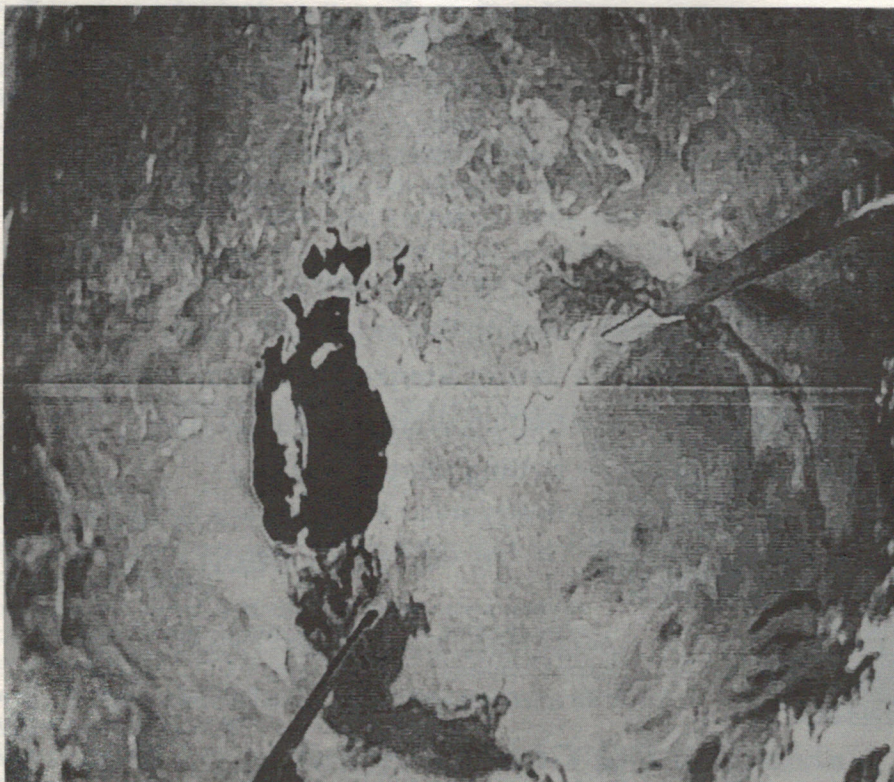


Figure 1. UO-22 Image of the Aral Sea

homogeneous medium gray smear. The pixel values might vary from 100 to 155, only about 20% of the 256 available values. Stretching contrast is accomplished simply by reassigning values: change 100 to 0, change 101 to 5, and so on up to changing 155 to 255. The full range of values are now being used and details like ridges and rivers become apparent. An advantage of using a computer to stretch contrast is that the machine does the tedious work after being given simple instructions by the user. One of the hidden advantages of stretching contrast is that the image processing program now has more computational "room" to alter the image further since all 256 values become available to be used.

Other alterations can be made. Some images have noise (abrupt changes in value between adjacent pixels) that may have been introduced by overloading of the analog-to-digital converters in the camera. A simple way to reduce noise is to instruct the computer to average the value of a pixel with the values of surrounding pixels, so a light pixel in a dark area would become dark. Another technique is based on a mathematical process of convolution that can be tailored to sharpen detail (akin to focusing a camera) or blur detail in an image. Since the image exists in computer memory, a user can zoom in on a portion of an image of interest. One can assign colors to the various pixel values to produce an image in "pseudo-color." Pseudo-color is especially useful for finding detail in ocean images. An ocean current may be only slightly brighter than the surrounding water, but slight differences in pixel value can correspond to rather different colors.

Hardware and Software

Image processing software is readily available for microcomputers and workstations. This article will concentrate on the Apple Macintosh and MS-DOS computers since these machines are likely to be found in the shack of the typical satellite operator. Commercial software is available, but shareware and public domain programs are almost as powerful. See the end of the article for information on how to acquire these software tools.

The real champion for image processing among personal computers is the Macintosh. The computer and monitor must be able to display 8-bit color, so that means Mac II and Mac LC models. The LC with 256k VRAM SIMM can support 8-bit color on the Apple 12-inch monitor only; with a 13-inch monitor, a 512k VRAM SIMM must be installed in the LC. All 8-bit displays can show 256 shades of gray, so these devices will show the data to the limits of resolution. While many users complain about the perceived high cost of Macs, consider that in early 1993 one can buy a Mac LC II with 4 MB memory, a 512k VRAM SIMM, and an 80 MB hard disk with a 14-inch color monitor for about \$1500. An

optional math coprocessor (highly recommended) is \$60.

There are many Mac image processing programs, but the one used for this article is NIH Image from the National Institutes of Health. NIH Image was originally developed to analyze medical images such as those from magnetic resonance imaging machines, but the program operates well with satellite data. Because the software is a work of the federal government, NIH Image is in the public domain. The program requires 8-bit color as mentioned in the previous paragraph. Both FPU and non-FPU versions are available, but an FPU for those Macs that do not have them (the LC and IIsi at this writing) will make operations significantly faster. NIH Image can import raster files easily as long as the number of lines, number of pixels per line, number of bits per pixel, and number of offset bytes of the file are known (568, 568, 8, and 0 for raw KO-23 images). Apple File Exchange can be used to translate files from a PC disk to the Mac format. NIH Image does not read GIF files directly, so use a GIF viewer like QuickGIF to convert the files to PICT or TIFF format. All the monitor photographs accompanying this article are of files processed with NIH Image on a Mac LC II.

Most satellite operators use MS-DOS computers for tracking programs and Pacsat software. While these machines can be used to process images, the display quality may not be as good as a Mac display. A VGA monitor can show only 16 shades of gray; most Super-

VGA displays can show only 64 shades of gray. Check equipment manuals for details. One MS-DOS image processing program that is useful is IMDISP. The program was developed by some NASA personnel, so it is in the public domain. IMDISP works with a variety of displays. IMDISP can read GIF files directly, so one can view GIF images downloaded from CompuServe or the Internet immediately. IMDISP can also import raster files as long as the particulars of the image format are known.

Examples

As mentioned previously, Figure 1 is an image of the Aral Sea. This was originally a GIF file in which the contrast had already been stretched. The Sharpen Convolution brings out the land-water interface more clearly. The horizontal line across the image is an artifact of the way the camera data is digitized; the objects that extend into the field of view from the right and bottom are spacecraft antennas. Compare this image with an older map or satellite image. The rivers that feed the Aral have been diverted in recent decades, so the water level has dropped drastically over the last 30 years. There is an image of the Aral taken by Space Shuttle astronauts during 1984 in the book *The Home Planet* (Addison-Wesley, 1988). The water level loss is visible even over just the last seven or eight years.

Figure 2 is a processed UO-22 image of Italy. Even with the contrast stretched, the original image was murky and had some noise (random light or dark pixels). First, the Reduce

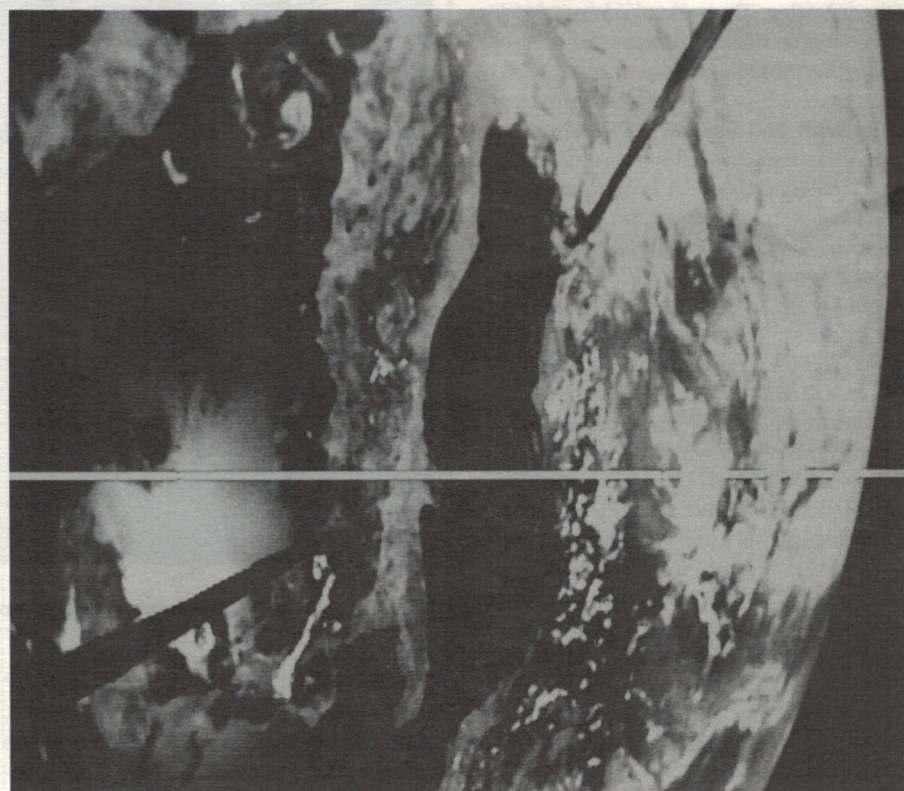


Figure 2. UO-22 Image of Italy

Noise algorithm was used to average the noise pixels into the background. Next, the Sharpen Convolution was used to bring out detail. Finally, the contrast was increased and brightness reduced to produce the photograph. The processing operations have "filled in" the pixel values so that all 256 are used.

The November/December 1991 issue of *The AMSAT Journal* featured a UO-22 image of the Persian Gulf that clearly showed the huge size of the smoke plumes billowing forth from the oil well fires in Kuwait. Incidentally, that photograph was reversed in the printing process. One of the things possible with satellite imagery is the ability to observe change over time. Figure 3 shows the Persian Gulf in August 1991 (left) and November 1991 (right). The fires were still raging in August, so the smoke plumes are visible. By November, the fires had just about been extinguished, so there are no huge smoke plumes. The figure is a photograph of a computer monitor with the images displayed at the same time in different windows. Both have had contrast stretched and the Sharpen Convolution applied.

The KO-23 narrow-field camera has a resolution of approximately 400 meters per pixel, small enough to make man-made structures visible from space. For an illustration, see Figure 4, a KO-23 image of Japan that includes the city of Hiroshima in the center right (at the top of a bay that is partially obscured by clouds). This image has had contrast stretched and the Sharpen Convolution applied. Note the detail in the coastal areas such as small islands and the hook-shaped peninsula near the left edge. The wakes of large ships should be visible with this camera when the sun is in the proper position.

Conclusion and Further Information

Image processing is well within the reach of most amateurs. One can bring out detail that was not apparent upon the first viewing. Thanks to Harold Price NK6K for providing numerous UO-22 and KO-23 images as well as the PC programs needed to extract images from download files. Thanks also to Jeff Ward G0/K8KA for technical information on the UO-22 and KO-23 imaging systems.

NIH Image is available for downloading from library 9 of the Macintosh Applications Forum (MACAPP) on CompuServe. The documentation, FPU, and non-FPU versions are separate files. NIH Image is also available by anonymous ftp on the Internet from [alw.nih.gov](ftp://alw.nih.gov) [128.231.128.251] in the `/pub/image` directory or from [sumex-aim.stanford.edu](ftp://sumex-aim.stanford.edu) [36.44.0.6] in the `/info-mac/app` directory. QuickGIF is available from the same CompuServe library and the same `sumex-aim` directory.

The latest version of IMDISP is available via anonymous ftp on the Internet from [ames.arc.nasa.gov](ftp://ames.arc.nasa.gov) [128.102.18.3] in the

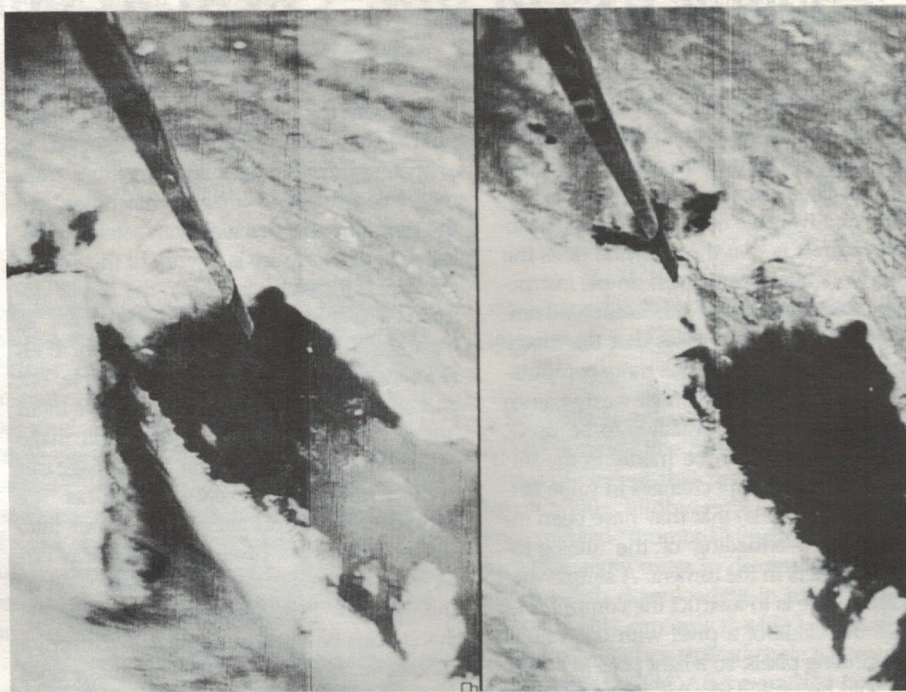


Figure 3. UO-22 Images of the Persian Gulf (August and November 1991)



Figure 4. KO-23 Narrow-angle Image of Southwest Honshu (Japan)

`/pub/SPACE/SOFTWARE` directory. IMDISP is not currently available from CompuServe.

GIF files of UO-22 and KO-23 images are available via anonymous ftp from [tomcat.gsfc.nasa.gov](ftp://tomcat.gsfc.nasa.gov) in the `/pub/amsat` directory. Some of these files are in library 5 of the

Hamnet forum on CompuServe. The [ames.arc.nasa.gov](ftp://ames.arc.nasa.gov) site has a huge number of space-related GIF files (Voyager images of the outer planets, Magellan radar images of Venus, etc.) in the `/pub/SPACE/GIF` directory. ■

Gateways to the 21st Century

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The Amateur Radio Service, about to transition into the next century, is facing the loss of sections of its vhf, uhf and microwave bands to commercial services. At present radio amateur use of these bands is somewhat haphazard and uncoordinated. This article presents an integrated plan for the use of those bands, that has the potential not only to safeguard those frequencies but to revolutionize the whole concept of amateur radio.

This paper discusses how Gateways may be used to integrate amateur radio terrestrial, satellite and interplanetary microwave communications. Such an integrated capability will provide capabilities that don't exist at this time and has the potential to transform amateur radio.

The Problem

In 1991, the Amateur radio service is still using technology based on that developed in the 1970's, with the sole exception of packet radio.

Recent advances in the state-of-the-art of computers and microwave technology have been ignored by the mainstream of radio amateurs. At present radio amateur use of these bands is somewhat haphazard and un-coordinated.

The Alternatives

There are three alternatives:

1. Do nothing.
2. Try to increase usage of these bands without providing new services.
3. Identify a new service suited to the properties of the bands, and propose a plan to move communicators into those bands.

Doing nothing will not make the problem go away. The bands are there and 1.2 GHz equipment is available commercially, but few communicators are moving up to that band from the 2 meter and 70 cm bands. This is because there is little incentive to move up to 23 cm. In general the higher the frequency, the more expensive the equipment that uses it. A new technology is rarely adopted unless it provides a new (and is or quickly becomes desired) capability [1].

The third alternative is thus the only choice that stands a chance of increasing the occupancy of those bands. The Gateway Project Proposal is herein identified as one way of providing an incentive to move the general communicators up in frequency. It also ad-

dresses several other problematic aspects of amateur radio and provides an integrated solution.

The Gateway Project Proposal

This project identifies Gateways as a mechanism for integrating amateur radio terrestrial, satellite and interplanetary microwave communications. Such an integrated capability will provide capabilities that don't exist at this time and has the potential to transform amateur radio.

The VHF, UHF and Microwave Bands

The microwave bands are allocated to the Radio Amateur Service as secondary allocations. At present radio amateur use of these bands is somewhat haphazard and un-coordinated. Radio amateurs have the use of these frequencies providing they do not cause interference to the primary users. Sections of the 70 cm the 23 cm bands have already been lost in various countries, 220-220 Mhz has been lost in the U.S.A and the prospect of further losses face us today. Our use of the vhf, uhf and microwave bands is twofold; terrestrial and satellite.

Terrestrial Use of Microwave Bands

Random contacts (QSO) on the microwave bands are few and far between. They seem to take place either as the result of a telephone call between the stations involved, or as the result of a scheduled expedition. In the latter case, the two stations involved drive out to different mountain tops, make a contact and write it up for the national magazine. All well and good, but hardly everyday use of the band. The microwave bands are not suited for random QSOs in the same way as the lower frequency bands. Figure 1 shows a typical situation with three stations, each using highly directional antennas. The antennas are so directional that each station cannot hear another. On the other hand, if a

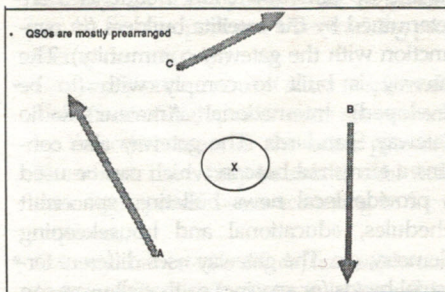


Figure 1: Microwave usage scenario

repeater was employed as shown in Figure 2, they would be able to QSO easily enough.

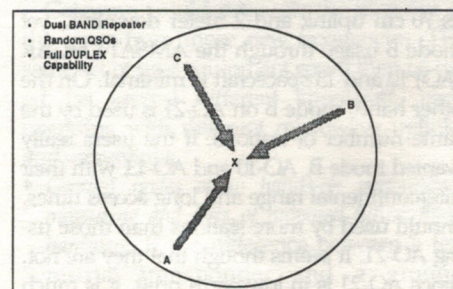


Figure 2: Repeater usage scenario

Repeaters are commonly used on 2 meters and 70 cm, yet they are very rare on the microwave bands. Why? Perhaps it is because microwave users tend to be experimenters, not communicators. From the experimenter's point of view, there is no challenge in repeater QSOs. From the communicator's point of view, a microwave repeater, as a copy of a 2 meter repeater, would not offer anything worthwhile. From the experimenter's point of view the only satisfaction is building the equipment. If we are going to make use of the microwave bands for communications, we have to do it in a way that offers something new. One such capability which seems to have been overlooked is full duplex communications.

AMSAT BBSs

Listing of BBSs which carry AMSAT News Service Bulletins (ANS) and the latest Keplerian Elements along with other information of interest to Amateur Radio Satellite Enthusiasts:

DRIG BBS
(214) 394-7438 Up to 38.4K, 8, N, 1

If you wish to add your BBS to this list, contact:

Doug Howard, KG5OA
(817) 292-6440
Compuserve 70233,3517

Satellite Use of the Bands

The 2 meter and 70 cm bands are the most popular of the vhf and uhf bands. The current spacecraft in development for the amateur radio service, shown in Table 1 [2], are still planning to use these bands. The 2 meter band is very crowded in most parts of the world. There is at present already enough interference (QRM) in the satellite section of the 2 meter band. This situation is only going to get worse.

Satellite users vocally want "Mode B" with its 70 cm uplink and 2 meter downlink, yet mode B usage through the AMSAT-OSCAR (AO) 10 and 13 spacecraft is minimal. On the other hand, mode B on AO-21 is used by the same number of stations. If the users really wanted mode B, AO-10 and AO-13, with their intercontinental range and long access times, should be used by more stations than those using AO-21. It seems though that they are not. Since AO-21 is in low earth orbit, it is much easier to get a stronger signal into and out of (albeit for shorter time periods) than AO-10 and AO-13. OSCAR users who are vocally demanding "Mode B" seem to be stating the problem in terms of a specific solution. What really they seem to be demanding is "Easy Access to communications satellites". They are stating it in terms of the current capability of AO-21, and their remembered capability of Mode B from AO-7.

Spacecraft Requirements

In the late 1970's, Karl Meinzer, DJ4ZC and AMSAT-DL studied the problem of providing worldwide amateur radio communications service with a single spacecraft [3]. These requirements were summarized as shown below [4].

1. All users want to get as much daily communications (operating) time as possible.
2. All users want to be able to work anybody they can (DX or local) taking advantage of the propagation characteristics of the medium (no skip zones).
3. At least 90% of the amateur radio population of the globe are located in the northern hemisphere.
4. The radio amateur population is distributed evenly over all geographic longitudes.

The optimal orbit to meet these requirements is the highly elliptical orbit, as used by the Molniya satellites. These spacecraft provide the desired communications capacity to the Soviet Union with much the same population distribution. Unfortunately, this orbit when used to provide Mode B communications suffers from marginal links due to the spacecraft on-board antenna and power limitations.

Let's now add the following observation to those above.

5. The majority of radio amateurs live in urban areas.

SPACECRAFT	COUNTRY	MISSION	LAUNCH DATE
ARSENE	France	Long Life Intercontinental AX.25 Communications	1992
KITSAT	Korea	Educational Construction Project	1992
TECHSAT	Israel	Educational Construction Project	1993
IT-AMSAT	Italy	Similar to AO-16 with science experiment.	1994
SUNSAT	S. Africa	Educational Construction Project	1994
MARS	Germany and an International Team	Interplanetary probe and long range communications relay	1995
AMSAT-PHASE 3D	Germany and an International Team	Long Life Intercontinental Communications	1995

Table 1: Amateur radio spacecraft under development

By introducing a Gateway into the communications path, users have easy access with good signal levels and do not have to worry about tracking the spacecraft. Satellite builders can build microwave communications systems. A new group can pick up the challenge of building both the gateways and designing the user equipment for accessing the Gateway. The state-of-the-art has changed.

A block diagram of the conceptual gateway is shown in Figure 3. The gateway is modular in construction. It consists of a wide band terrestrial receiver and transmitter using frequencies selected by the local gateway group. The satellite up and down link frequencies are determined by the satellite builders (in conjunction with the gateway community). The gateway is built to comply with (to be developed) International Amateur Radio Gateway Standards. The gateway also contains a terrestrial beacon which can be used to provide local news bulletins, spacecraft schedules, educational and housekeeping telemetry, etc. The gateway uses different terrestrial bands (or spacing) so that all users can receive their own transmissions.

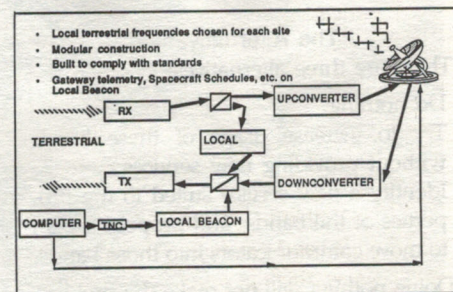


Figure 3: The conceptual gateway

The Conceptual Gateway

Satellite Gateways were proposed and described by this writer in 1978 [5][6]. In the 1970's the technology to use gateways was not practical, in the 1990's it is. Consider how the gateway would work. Figure 4 shows a typical satellite usage scenario at some particular instant of time. In the upper part of Figure 3, stations A, B, C and G can access the satellite to work each other or any DX that is about. Station A is blocked by the hill that station G lives on. If a gateway is located atop the hill together with station G as shown in the lower part of Figure 3, then A, B, C and G

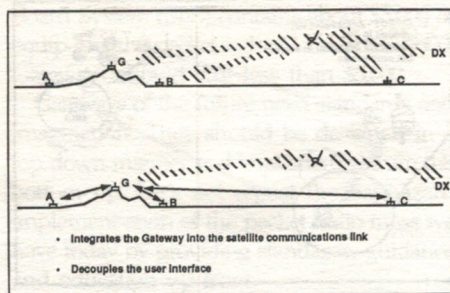


Figure 4: A typical satellite usage scenario

all have equal access to the spacecraft. The gateway acts as a second transponder in series with the spacecraft and decouples the user interface to the spacecraft. Note that the gateway does not preclude individual access to the spacecraft by any station.

Conceptual User Equipment

User equipment is also modular. The example discussed in this section uses 1.2 GHz as the user transmit frequency and the 2.4 GHz band as the user receive frequency. This frequency pair has been chosen because 1.2 GHz transmit is used as the Mode L uplink and 2.4 GHz is the Mode S downlink. A non rotatable microwave antenna is aimed at the gateway. This antenna may be placed on a mast, roof or balcony. Attached to it are the up/down converters which convert the gateway signals to those used by the 2 meter and 70 cm equipment in the radio shack. This gives the user Mode B in the shack and minimizes the radio frequency (rf) attenuation in the cables between the antennas and the radios. DX can be worked without towers and beams. The equipment also contains a simple self-monitoring capability to allow the user to verify that the equipment is operational. The equipment can provide digital or analog communications or a mixture. Real-time video is also a possibility. Suitable low cost equipment for users at these frequencies has already been described in the literature. [7][8].

Linking Gateways.

When wide band gateways are established in urban areas, there is no reason why links should not be set up between gateways in neighboring areas, much in the same way that nodes link packet radio local area networks (LAN). A conceptual linkage along the east coast of the USA is shown in Figure 5. From

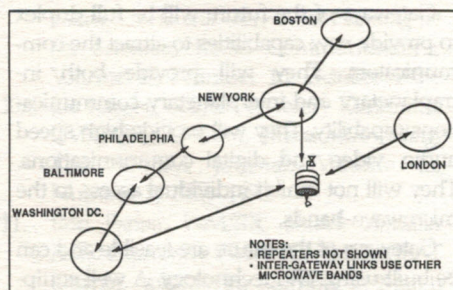


Figure 5: Linked gateways

the user's point of view, there is no difference if the gateways are linked by terrestrial or satellite nodes. The actual inter-gateway links would also use a pair of microwave bands. The conceptual gate way link node is shown in Figure 6. It is a conventional design and

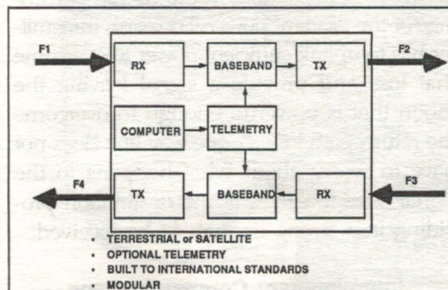


Figure 6: Conceptual gateway repeater or node

uses modular construction. It is also built to standards. The same block diagram can be applied to a satellite or to a terrestrial node. One way of using linked gateways is by frequency division. This approach is similar in concept to the UK 2 meter band geographical band-plan of the 1960-70 timeframe [9]. Figure 7 illustrates the passband of a gateway with two terrestrial links and one satellite link.

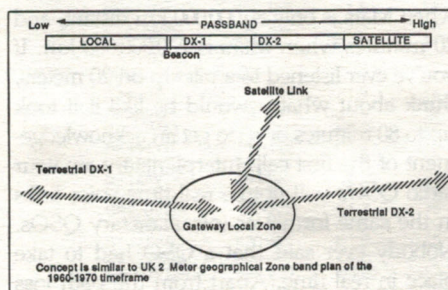


Figure 7: Conceptual gateway spectrum use

Users would choose which link they wish to access by transmitting in the relevant part of the passband.

Advantages of the Gateway

Gateways have several advantages, some of which are described below.

- Gateways do not preclude individual radio amateurs from access to space craft.
- Gateways provide easy user access. Antennas can be fixed in position. User tracking problems do not exist.
- Gateways provide controlled access to spacecraft. The effects of high power users are only felt by the other users of the same gateway. These irate users may be able to deal with their high power users according to local customs.
- Gateways can provide full duplex communications capacity. This capacity is lacking from most present day amateur radio contacts.

- Gateways allow spacecraft to be simpler. Spacecraft will not have to contain a number of transmitters and receivers for the different modes. Users will no longer have to remember operating schedules for when particular modes will be useable.
- Gateways allow spacecraft builders to tackle higher frequencies. Spacecraft for amateur radio are built by volunteers for the challenge. They are interested in pioneering new techniques and new frequencies.

Gateways would decouple the majority of the users from these new frequencies. The same set of user equipment could then be used for several different spacecraft, each operating with different microwave uplinks and downlinks.

- Ground nodes allow hands-on performance measuring and tests of proposed future flight hardware. If the difference between a terrestrial transponder and a ground transponder on a node is only the environment, several versions of proposed hardware and software can be ground tested by real users in different parts of the world before flight. Non viable designs would be discarded without incurring the cost of the launch and the embarrassment of the users finding out how unsuitable the hardware really was. On the other hand, suitable techniques that fail to become active in orbit may be demonstrated and become widely adopted on the ground.
- Gateways provide a training ground for developing new technical talent for the radio amateur space hardware development program. Up to now, amateur spacecraft are built to order. A launch date is obtained, and the team strives mightily to meet that date. So far they have all succeeded in that the hardware has been aboard the rocket when it lifted off. This pressure is real because rocket payloads have to be balanced. If a date is missed, the launch agency might never allow amateurs another chance, and there are very few launch agencies. The project team have to allocate the work to people whose performance capabilities are known. They cannot take a chance on an untried person, and cannot take the time to give that volunteer a chance. New volunteers are caught in a Catch-22 situation when trying to join existing teams.
- New groups on the other hand can develop their own spacecraft, but to form a group, a particular nucleus has to exist. Ground nodes on the other hand can be built by clubs, technical schools and other starting groups. They can take the time to do it right. They don't have a tight launch date to meet.
- Gateways can also reduce the cost of accessing satellites for the individual users. They can use the same equipment they use for terrestrial QSOs for spacecraft access. In fact, gateways make the communications link

transparent. If the terrestrial gateways get to be linked in a manner similar to the packet radio network of today, the only way users may know that they are communicating via a satellite is by the time delay on the signals.

Path Attributes

Consider the path loss and noise attributes of the microwave link. The goal of the transmitting station is to put a useable signal into the antenna socket of the distant receiver. For any given path between two stations. The received signal strength is a function of the gain of the antennas and the cable losses at each end of the link as well as the attenuation over the distance of the link. These factors have been worked out and the received signal levels at various frequencies for different link parameters can be readily predicted. The second major factor to impact microwave communications is noise. Atmospheric noise is both natural and man made. Most radio amateurs living in urban environments suffer from the effects of man made noise. Noise is also present in the front end of receivers. Any communications link design such as that shown in Figure 8 has to take noise into account. Adding transponders or gateways in

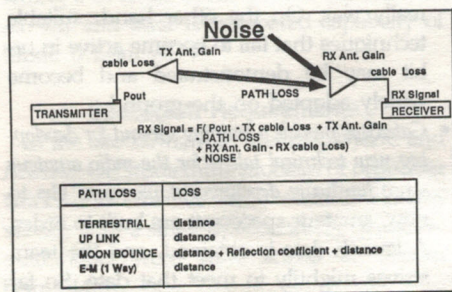


Figure 8: Path attributes

series will add noise to the link, a phenomenon which will have to be accounted for. A typical example of the communications capacity of a link using a 100 Watt morse code transmitter, with identical dish antennas at each end of the link, in a 100 Hz bandwidth is shown in Figure 9.

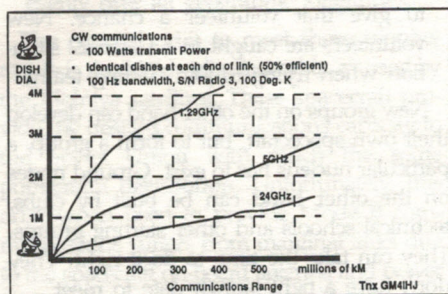


Figure 9: Communication ranges

The limiting factor seems to be distance. A 1 meter dish provides communications

capabilities out to 450,000,000 km at 24 GHz. A 2 meter dish will provide QSOs at 1.2 GHz out as far as 100,000,000 km. Given that the moon is at a mean distance of 384,399.1 km from the earth, why does moonbounce require a lot of power? Well in moonbounce, much of the power is lost at the moon because it only reflects a minuscule percentage of the incident power. The earth transmitter has to uplink sufficient power to overcome that loss and provide a signal leaving the moon that is powerful enough to overcome the return path loss. A one way link does not have to worry about what happens to the signal once it arrives at the destination providing it is strong enough to be received.

Interplanetary Communications

A range of 100,000,000 km provides communications capabilities with future bases on the moon or Mars. The distance between the Earth and Mars varies between about 80,000,000 and 230,000,000 km depending on the positions of the planets as they travel along their own orbits around the sun. Overcoming the path loss is only one problem that has to be faced by the radio amateur configuring for interplanetary communications. The major problem will be the time delay. The one way travel time for a signal between the Earth and Mars varies between about 4 minutes when Mars is only 80,000,000 km distant, and 20 minutes when Mars is 220,000,000 km. If you've ever listened to a pile up on 20 meters, think about what it would be like if it took up to 80 minutes or so to get an acknowledgement of the first call. Interplanetary amateur radio QSOs will not be real time voice links in the same format as intraplanetary QSOs. Nobody ever said that a QSO had to take place in real time. Apart from the path loss and the time delay, both planets are rotating, so there will be Doppler shift on the signals. For any station on the amateur radio station located on the surface of the Earth (earthstation), Mars will only be above the horizon for a few hours each day. There is no guarantee that when Mars is viewable by an earthstation, Mars base will be able to see the Earth let alone the same earthstation. These problems are not insurmountable, PCs can handle all the math involved, but they do tend to make direct inter-planetary communications difficult. If suitable spacecraft were in orbit about both planets they could make inter-planetary communications much easier. However, getting these spacecraft built and into suitable orbits may be difficult. The concept of direct and indirect interplanetary communication is shown in Figure 10.

Perhaps, radio amateurs will need not build their interplanetary relay satellites. Amateur radio seems to be in space to stay. It is an important part of MIR daily activities [10]. It has flown on the Space Shuttle and amateur radio may even be manifested as personal equip-

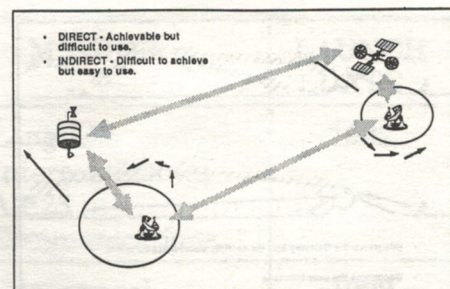


Figure 10: Direct and indirect interplanetary communication

ment belonging to the astronauts. If that happens, any flight carrying an astronaut who is a radio amateur will have some amateur radio activity. Operations from the shuttle suffer from the lack of an outdoor antenna [11]. Bulkhead fittings are present on the vehicles so the only technical problem preventing the attachment of suitable antennas in the payload bay is the cost of the paperwork required to document the changes. The National Aeronautics and Space Administration (NASA) is currently planning for upgrades to the NASA Communications Network, Space Station support and the new Customer Data Operations System (CDOS). Amateur radio needs to get their inputs into the system now while it is in the planning stage. If they are in from the beginning, they are in at minimal cost. A conceptual integrated approach is shown in Figure 11.

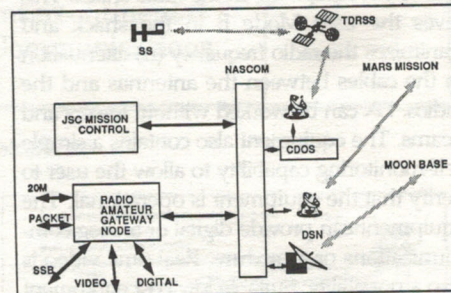


Figure 11: Conceptual integration of amateur radio into space communication links

Summary

Gateways of the future can radically change amateur radio as we know it today. A Plan for an integrated terrestrial and satellite radio amateur communications network is a plan for the future of our microwave bands.

Gateways of the future will be full duplex to provide new capabilities to attract the communicators. They will provide both intraplanetary and interplanetary communications capability. They will provide high speed audio, video and digital communications. They will not inhibit individual access to the microwave bands.

Gateways of the future are feasible and can be built using 1991 technology. A well equipped high frequency (HF) packet radio Bulletin

Board System (BBS) contains about \$5,000 of equipment, a packet radio Node, about \$500. Gateways should cost less than \$5,000.

Gateways of the future need standards and imagination. They should be designed in a top down manner and implemented from the bottom up. Let's not repeat the haphazard implementation of the packet radio mess we have today by providing standards, guidance and education up front.

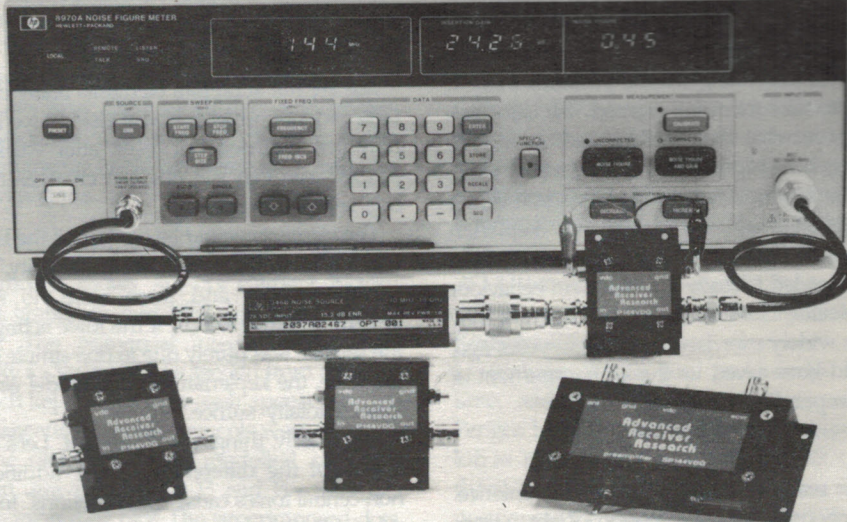
Gateways of the future provide something for everybody. Users get easy access to satellite and DX communications and a host of new services. Satellite builders get to play with higher frequencies. Best of all, they provide a plan for the use of the microwave bands in a manner for which the bands are best suited. Such a plan may also tend to safeguard those bands for the Amateur Radio Service.

In the past radio amateurs have acquired boxes and asked themselves the question "How can I use them?" This paper has presented a vision of the future. Perhaps the question should be posed differently. "I have a vision of the future, how can I get the black boxes to implement the vision?"

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SP220VDA	220-225	<1.3	15	0	DGFET	\$67.95
SP220VDG	220-225	<0.55	20	+12	GaAsFET	\$109.95
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May the Force Be With You

(This article first appeared in *Amsat-UK's Oscar News*, December 1992)

By: James Miller, G3RUH

We are so used to keplerian elements as the basis for calculating satellite positions that we tend to take them for granted. We don't ask anymore what they really mean, or indeed how good a representation they actually are. In this article I want to explore some of the goings-on that are hidden by keplerian elements. That will lead to a discussion of the tools needed to study the long term behaviour of satellites like Oscar-13, tools that had they been widely exercised only a few years ago, would have saved us the embarrassment of the impending loss of this satellite!

Why Keplerian Elements?

The reason we use "keps" is convenience. The six quantities (Inclination, Right Ascension, Eccentricity, Argument of Perigee, Mean Anomaly and Mean Motion) plus a time-tag have a geometric interpretation which is easy to assimilate, and they lend themselves to very straightforward numerical manipulation for calculating the body's future position and velocity.

Alternative Representation

One thing to recognize is that these six elements are not a unique representation of a satellite's orbit. Any six independent quantities would suffice. In particular, six rectangular coordinates, 3 for position (R_x, R_y, R_z) and 3 for velocity (V_x, V_y, V_z) achieve the equivalent thing. This is the most direct specification of a satellite's motion. Just consider it as a lump of metal at a certain point in space, with a certain velocity at a specified time. If you start from this concept, all sorts of interesting things flow.

For a start, how do you predict the future position of the satellite? Quite easy; integrate the equations of motion from the known starting point. After all, it's only a lump of mass subject to known forces. If we know where it is now, know those forces, we have the acceleration, and hence the velocity and thus position at any time in the future. There is nothing complicated, mysterious or chaotic about this.

It is perfectly possible to hop from one representation to the other; given a position and velocity, there is a set of osculating ("kissing") keplerian elements exactly equivalent, and vice versa - see [2], chapter 2.4.

The set of 6 numbers $R_x, R_y, R_z, V_x, V_y, V_z$ are constantly changing as the satellite whizzes round its orbit. But excepting the epoch time-tag, the equivalent keplerian set's numbers are constant. This of course is one reason we prefer to use keps.

Variable Constants

But are the keplerian elements really constant? No, not quite! For why else do we have new sets churned out week after week by NASA? You can see obvious changes from one set to the next.

The elements would be constant if the Earth was a perfect sphere of uniform density, had no atmosphere and there were no solar system! In other words, if the force acting on the satellite was purely due to one simple central force, the keplerian element model would indeed totally suffice.

Fortunately, things aren't like that. Let's take a look at the differences. These additional non-central forces cause "perturbations" to the nominal orbit.

Perturbations

By far the most significant is that due to the bulge of the non-spherical Earth. The local vertical only points at the center of the Earth if you are at the equator or at the poles. In between, the departure is as much as 0.2 degrees. And it's the same in space; a satellite can be pulled as much as 0.2 deg away from the non-central direction. The average effect on an orbiting satellite is substantial. In particular, right ascension (RAAN) and argument

of perigee change noticeably up to several degrees per day. Thus prediction programs, using keplerian elements as their input, have to account for this gross effect. They do it, not surprisingly, by steadily changing the worst affected elements as time goes by. The compensation is predictable, and entirely adequate for amateur tracking purposes.

I wrote "steadily"? But how in reality can it be so? As it passes over the equator, gravity's pull is centrally directed, so there is no deviation at that instant. But when the satellite is say at 45 degrees latitude, there is an off-center pull. So RAAN and argument of perigee must be wobbling through an orbit period. This is worth following up!

Microscopic View

In order to study the fine structure of orbital motion, you have to go back to basic mechanics; the position and velocity approach defined by $R_x, R_y, R_z, V_x, V_y, V_z$, and treat a satellite as an object subjected to calculable forces F_x, F_y, F_z .

Figure 1. shows what really happens to Oscar-13's keplerian elements during the course of two orbits. The satellite starts off around apogee (on 1992 Jan 1) according to its known position and velocity at that time.

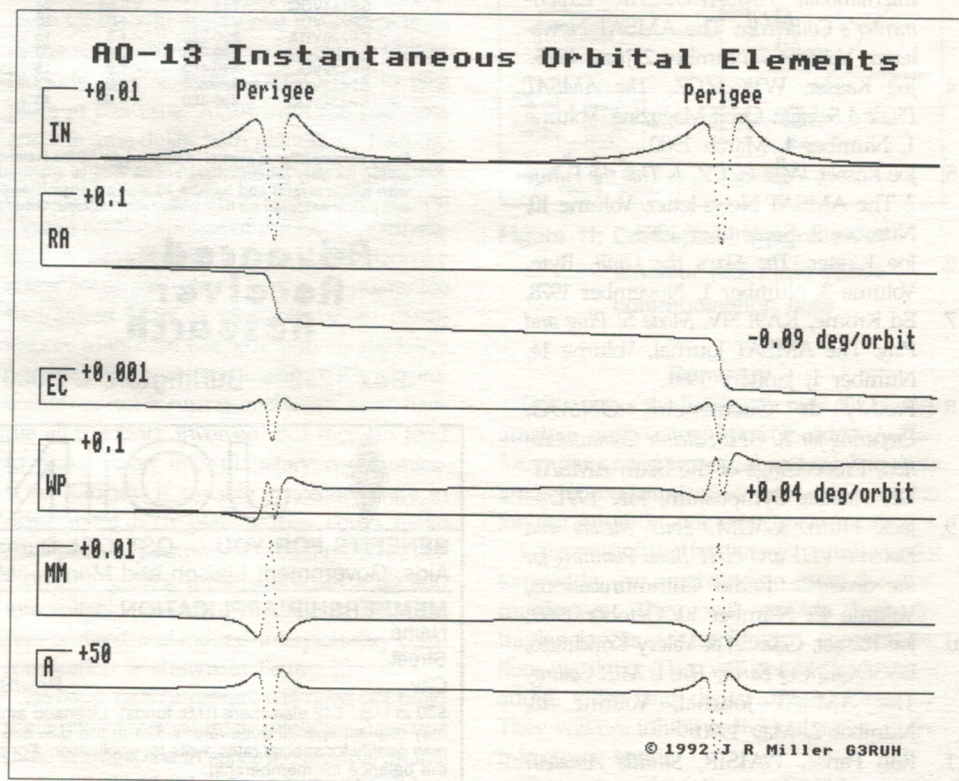


Figure 1. Keplerian elements are not constant! These graphs show the small variations in Oscar-13's parameters during the passage of two orbits.

It is subjected to only two components of force; basic gravity plus the first coefficient representing the bulge (in the expression of the Earth's gravity field this quantity is known as J2). The equations of motion are progressed for one minute. Then the instantaneous keplerian elements are computed. This is repeated over and over until two orbits have been completed. The plots show the variation in each element compared with the starting set used.

These variations in the keplerian elements, though small, are quite striking! At perigee, semi-major axis (A) makes a 100 km hiccup, mean motion transiently increases by 1/100 rev/day, eccentricity (EC) and inclination (IN) have similar lurches. Right ascension (RA) and argument of perigee (WP) do indeed show the expected secular changes; but these are in no way "steady". As the curves show, for AO-13, RA and WP actually change by steps at perigee! So the conventional prediction program designed on the basis of steady changes in these parameters inevitably introduces short term errors. They average out over an orbit, but the transients in this example amount to about 10 km in position, and several m/s in velocity.

So we have established that conventional prediction programs based on keplerian elements have built-in limitations. They only cope with one term (J2) of the Earth's bulge. What of the other forces? Atmospheric drag figures quite dominantly for low Earth orbiters. To a first approximation its effect is to reduce the satellite's momentum, and this shows up as a gradual decrease in semi-major axis or equivalently an increase in mean motion. So the element sets feature a quantity called "drag", half the rate of change of mean motion. It's a good approximation in some cases, but is certainly inadequate if the orbit has a low perigee and high apogee.

Sun and Moon's Pull

Lets look more closely at other forces that standard programs ignore (apart from items 1 & 2 below), which significantly affect Oscar-13:

Max Value

- | | |
|---------------------------------|----------|
| 1. Standard gravity | 1.0 g |
| 2. Non-spherical Earth, J2 term | 1E-3 g |
| 3. Non-spherical Earth, J3..J7 | 1E-6 g |
| 4. Moon's differential pull | 6E-7 g * |
| 5. Sun's differential pull | 3E-7 g * |
| * at Rsat= 40,000 km | |

Items 4 and 5 don't seem like much; less than a millionth of "g". But AO-13 weighs 100 kg on the ground, so this force is of the order of 50 milligrams. Not so small after all! If it acted steadily for 1 day, the accumulated movement would be nearly 20 km. Clearly luni-solar forces cannot be completely ignored.

What causes these "differential" forces? The Sun is pulling on the Earth and the satellite. If the latter is close to the Earth, the pulls are virtually identical. But if like AO-13, the satellite happens to be 40000 km nearer (say) to the Sun, it experiences a slightly greater pull than the Earth does, so moves slightly towards the Sun. And sometimes, of course, it moves away. Over a long period, these perturbations accumulate, and show up in the instantaneous keplerian elements as substantial variations.

Long Term Elements

Figure 2 shows AO-13's element history since launch in mid 1988, up to the end of 1992. The numerical integration program (Rx,Ry,Rz,Vx,Vy,Vz) was seeded from the post launch keps. Thereafter each apogee, the instantaneous keplerian elements were dumped to the plot. The forces modelled are Sun, Moon, gravity plus J2, J3 and J4.

An interesting plot! The superimposed dots are values from a hundred or so NASA keplerian element sets. Very apparent is the extra-ordinary noisiness of NASA data, particularly in Inclination. This is no slight on NASA; the elements they publish are designed to be used in conventional programs in a very specific way, not to be plastered about on plots such as this! [3].

However the general agreement in all parameters is excellent. The fine structure on the inclination plot is caused by the Moon, while the diurnal wobbles are caused by the

Sun. Given that standard programs use spot values for elements that are in reality clearly varying, a spot conventional position calculation for the satellite's position is always going to be in some error, by perhaps as much as 50-100 km!

Back to the Future

In mid-1990 people began to notice the rising trend in eccentricity, with the consequent reduction in perigee height (Hp). Then, by a quite unjustified linear extrapolation, confidently predicted Hp would fall to 200 km (the upper atmosphere) in mid-1992, and AO-13 would burn-up shortly thereafter.

This was immediately refuted by Dr Victor Kudiella OE1VKW [7] who had been quietly working on this very problem for some time, and already knew the true answer. Perigee height would minimize at about 600 km in 1992, rise up to 850 km in 1993/4, and then monotonically reduce again, thus postponing the catastrophe until late 1996. See figure 3.

Direct Integration

Integration of the equations of motion proceeds thus. The body is at a position in space, $\mathbf{r}$, where the use of bold indicates that this is a 3-dimensional quantity. The body is subject to a force per unit mass of $\mathbf{F}$.

So the problem formulation is simply $d^2\mathbf{r}/dt^2 = \mathbf{F}$. This is merely Newton's first law; acceleration is proportional to force and in the direction of that force!

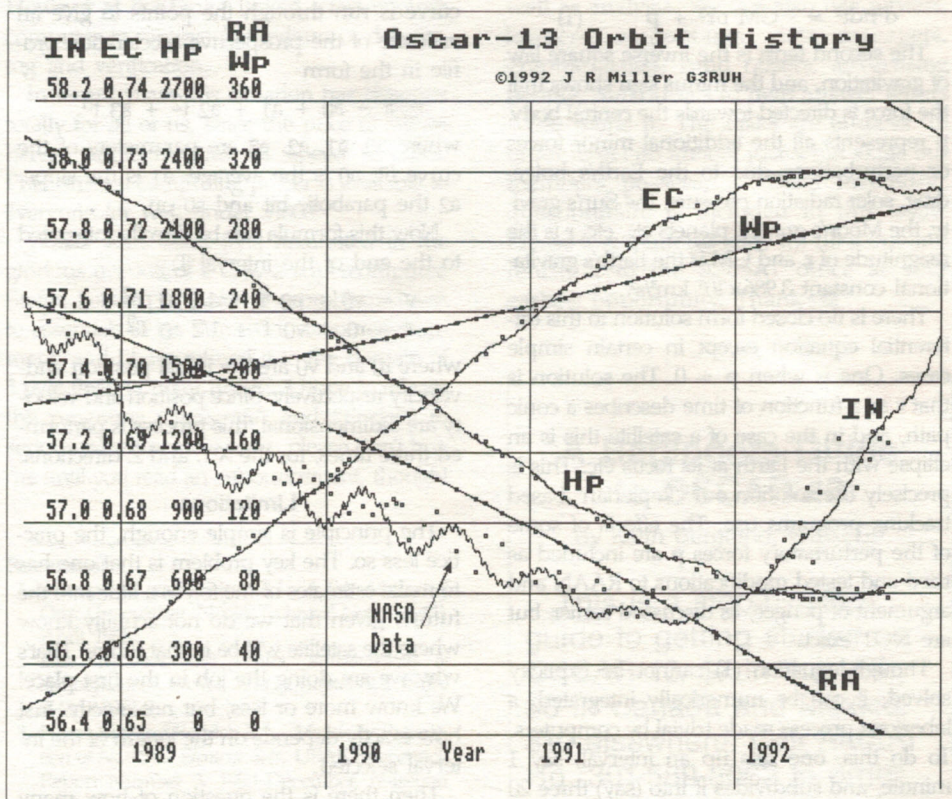


Figure 2. Oscar-13 keplerian element history, from launch 1988 to end 1992. Curves are from numerical integration of the equations of motion, and plotted points taken from NASA 2-line keplerian element sets.

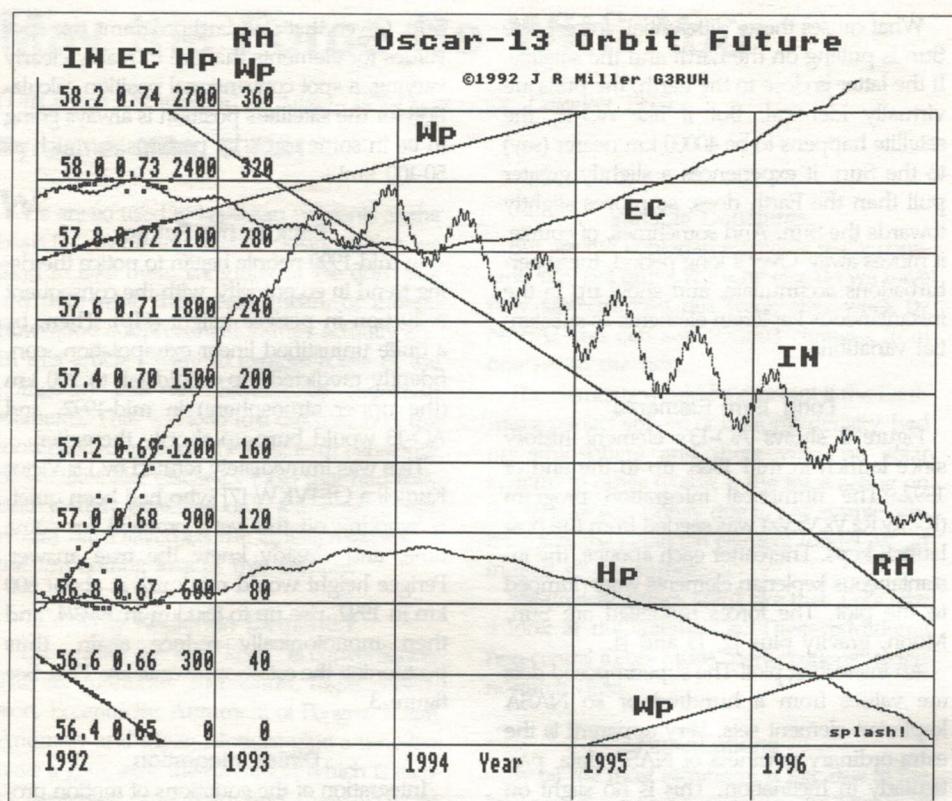


Figure 3. Oscar-13 keplerian elements' predicted future. From 1994 eccentricity starts to increase with the attendant reduction in perigee height (hp). In early 1996 the satellite will start to be dragged down by the Earth's atmosphere, resulting in its demise later in the year.

For an Earth satellite, this is mainly the pull of the Earth:

$$d^2r/dt^2 = -GM/r^3 + p \quad (1)$$

The second term is the inverse square law of gravitation, and the minus sign shows that the force is directed towards the central body. p represents all the additional minor forces or perturbations due to the Earth's bulge, drag, solar radiation pressure, the Sun's gravity, the Moon's gravity, planets etc. etc. r is the magnitude of r , and GM is the Earth's gravitational constant $3.986 \times 10^5 \text{ km}^3/\text{s}^2$.

There is no closed form solution to this differential equation except in certain simple cases. One is when $p = 0$. The solution is that r as a function of time describes a conic path, and in the case of a satellite this is an ellipse with the Earth at its focus etc. This is precisely the solution our "keplerian" based tracking programs use. The effects of some of the perturbatory forces p are included as tried and tested modifications to RAAN and argument of perigee, as discussed earlier, but are NOT exact.

Though equation (1) cannot be explicitly solved, it can be numerically integrated, a laborious process made trivial by computers. To do this, one sets up an interval, say 1 minute, and subdivides it into (say) three 20 second sub-intervals. At each of the four points the expected force as given by the right

hand side of (1) is calculated. The force will vary slightly through the interval. A smooth curve is run through the points to give an estimate of the prospective acceleration profile in the form

$$a = a_0 + a_1 + a_2 t^2 + a_3 t^3$$

where a_0 , a_1 , a_2 , a_3 are parameters of the curve fit; a_0 is the average, a_1 is the slope, a_2 the parabolic bit and so on.

Now this formula can be directly integrated to the end of the interval T :

$$v = v_0 + a_0 T + 1/2 a_1 T^2 + \dots$$

$$r = r_0 + v_0 T + 1/2 a_0 T^2 + \dots$$

where r_0 and v_0 are the initial position and velocity respectively. Since position and velocity are 3-dimensional, this process is performed three times, for the X,Y, and Z directions.

Limitations

The principle is simple enough, the practice less so. The key problem is that one has to make estimates of the forces a little into the future, given that we do not actually know where the satellite will be in that future. That's why we are doing the job in the first place! We know more or less, but not exactly. Just how exactly depends on the length of the interval selected.

Then there is the question of how many sub-divisions to make. Too many steps, and time is wasted in computation, and numerical

round-off errors can accumulate. Too large-sized steps, and gross modelling errors will arise. These matters have occupied mathematicians and engineers for at least a century, and have resulted in whole libraries of books on the topic. Numerical integration is both a science and an art. Fortunately, from our point of view, the success of a particular integration strategy can be gauged against the known behaviour of existing satellites. For Oscar-10 and Oscar-13 we have many years' accumulated NASA data.

Enter ENCKE

Direct integration of equation (1) generally takes a lot of computing time and requires great precision if the solution is not to diverge from reality. The problem isn't new. It first arose in the 19th century when astronomers wanted to predict the motion of comets subject not only to the central body force, but also to minor forces. The primary motion, as with a satellite, is known fairly accurately; it is an ellipse. So why expend all that labour calculating the known. Why not re-formulate the problem to exploit the known attributes of the solution, and concentrate on the small deviations that result from the perturbing forces? By removing the known part of the solution, much longer time intervals can be selected, and considerably less precision used in the calculation, with attendant speed increases.

Encke (ca. 1857) devised an approach, when slide rule and log tables were the zenith of computing, and his technique is still used very successfully today. The true equation of motion is as before:

$$d^2r/dt^2 = -GM/r^3 + p \quad (1)$$

We have a nominal reference solution to the simple two body problem, witness our familiar keplerian element type programs. It is the solution to:

$$d^2r_e/dt^2 = -GM/r_e^3 \quad (2)$$

where r_e is the reference position, and there are no perturbation forces, so r_e follows an elliptic path. Now define the small difference d between the true path and the reference as: $d = r - r_e$. Subtracting (2) from (1) gives:

$$d^2d/dt^2 = -GM(r/r^3 - r_e/r_e^3) + p \quad (3)$$

The term in brackets can be reformulated in terms of d yielding:

$$d^2d/dt^2 = -GM(d/r^3 - r_e/r_e^3) + p \quad (4)$$

where

$$q = (r^2 + r \cdot r_e + r_e^2)/((r + r_e)r^3 r_e^3) \cdot (d + 2r_e) \cdot d$$

Equation (4) is then numerically integrated as before. When d gets larger than a predetermined amount, say a few tens of kilometers, then the reference keplerian element set can be reset from the sum of the old reference and the current deviation, and d zeroed. [2, 4].

Guidelines

I have examined the performance of both techniques using AO-13 as a test case. My objective was to find the fastest method of computation.

I tried using 5-byte and 8-byte floating point arithmetic, experimenting with variable step sizes at different parts of the orbit, simplifying Moon and Sun models and so on. This is a summary of my conclusions:

- Though Encke's method can use 6x bigger time steps than the direct integration approach, the TOTAL amount of computation is still about the same, so both methods are equally good as far as speed goes.
- Encke's method is VERY accurate using 5-byte floating point over 10 years or more, whereas direct integration using 5 byte floating point is not. Direct integration MUST use 8 byte floating point arithmetic.
- 5 byte floating point Encke is a LOT faster than 8 byte direct integration!
- Since the forces depend only on the satellite's position (drag ignored), a Runge-Kutta integrator for $r'' = f(r,t)$ is appropriate, and sixth order (RK6) has proved entirely adequate. Fourth order (RK4) required too small step sizes for the same accuracy, and took longer overall.
- Step sizes: I found $dt = 600 \cdot (R/6378)^{1.2}$ worked well with Encke's method, and $dt = 100 \cdot (R/7000)^{1.5}$ with direct integration. Many variations are possible, but there appears always a minimum computation time that cannot be further reduced without significant errors.
- In Encke's method, J2 should be built into the keplerian reference orbit generator in the usual way, as precessions to RAAN and argument of perigee.
- Since the instantaneous (osculating) keplerian elements vary considerably through an orbit (figure 1), always start up a run at apogee, and always extract keplerian elements for analysis at apogee. Otherwise you get correct, but misleading, results.
- Modelling simplifications. Earth's bulge J3 and J4 have negligible effect and can be ignored. The Sun's orbit can be treated as circular with very little error. The Moon can be treated as being in a simple elliptic orbit, ignoring most of the myriad of Brown's expansion terms, with very little error. You CANNOT omit the Moon altogether despite its apparently short amplitude wobbles on traces in figures 2 & 3.

Unlucky 13!

We were VERY unlucky with Oscar-13. Armed with these splendid analytic tools, it is a simple matter to explore what might have been. A little thought shows that, for an AO-13 type orbit, the long term orbit behaviour is largely determined by the initial

values of RAAN and argument of perigee. And we got just about the worst possible case! We find for example that if the satellite had been launched only 1 hour earlier, or equivalently two weeks earlier, the 15 degrees less RAAN would have been just enough! Naturally, such a change to the launch would not have been possible since Amsat was very much the free-ride passenger.

But a real alternative would have been to accept our given launch, and let the RAAN drift through precession to some desirable value. This could indeed have been done by deferring the second burn for a couple of months. However, whether or not the Sun angle would have been favourable at the burn attitude at that time you will just have to work out for yourself!

The Future

We will NOT be unlucky with P3D. These tools, to study the long term features of proposed orbit(s), have been developed by several workers. There is a growing body of amateur literature which I have summarized below [7-13]; I believe it is complete at the time of writing. Kudielka, Clark, Eckart, and myself have used quite different numerical techniques and models, and all come up with the same answers for Oscar-13.

So what is needed now is further simplifications, more speed, and then program(s) dissemination. My own investigations started in December 1987, prompted by the work of Victor Kudielka who had recently written to me [6], and by reading [2]. However at the time I lacked a fast enough computer to remove the tedium of debugging and verification.

In recent years this situation has changed totally for all of us, since the price of silicon halves annually, and its speed doubles. Phenomenal computing power is available to everyone for well under \$1000.

Whilst Tom Clark [8,9] luxuriated in the glorious overkill of a Cray-2 supercomputer, Stefan Eckart [10] pared the problem down to essentials in his Sun work station environment, and I have refined it to the domain of 5 byte floating point BASIC. I hope to release the programs ("Integrate" and "Encke") to serious experimenters soon; please don't bug me until you read an announcement, though!

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Apogee View

(continued from page 3)

Your Assistance Always Welcome

AMSAT is always looking for help in a number of areas. The need is not limited to technical disciplines, although they certainly represent some of the areas of interest. Nor is electronics the only technical field in which we can use assistance. More are needed who can do mechanical and thermal design work as well as analysis. We can also use writers, lawyers, accountants, data managers, graphic artists, fund raisers, advertising people, individuals to help answer letters - you name it. The tasks are endless. In order to get an idea of just what skills our members possess, a "skills inventory" questionnaire is included in this issue. Please tear it out (or copy it), fill it out and return it to the AMSAT office at your earliest opportunity. Thank's■

A Beginners Guide to OSCAR 13

By Keith Berglund, WB5ZDP

This is a step-by-step guide to getting started on OSCAR 13. \$7 in the U.S., \$8 in Canada and Mexico, \$10 elsewhere. Call AMSAT Hq. 301-589-6062 to order.

Measure AO-13 Squint Directly!

Squint Angle is the angle between the spacecraft's spin axis and the observer. It is calculated knowing the satellite's orientation (Alon/Alat), and that's found from Sun and Earth sensor data. Wouldn't it be useful to be able to measure Squint Angle directly? You can!

By: James Miller, G3RUH

A chance flit through an article [1] on the recovery of Giotto (to ready it for another mission) included an interesting comment. "You should never mount your antenna straight on a spinning spacecraft; you put it offset so you can see the doppler". In a flash I had an idea.

The AO-13 mode-S antenna is mounted off center. So, when squint angle is not exactly zero, the antenna must appear to the observer to be moving back and forth along the line-of-sight cyclically by a few tens of cm. This is a significant fraction of a wavelength at 2.4 GHz, and must show up as phase modulation on the beacon or a transponded carrier. So it should be detectable as beacon FMing. If we measure the deviation of that FM, since it is proportional to the magnitude of the 'wobble', we can calculate Squint angle directly!

This also offers us a system of attitude measurement totally independent of Sun and

Earth sensors, optics and the like. Furthermore, the technique and its variations would be extremely useful for the forthcoming P3D satellite.

Why didn't I think of this years ago? Thus excited, I embarked on some experiments that anyone can duplicate.

Calculations

A few seconds scribbling revealed the following.

Range oscillates by:

$$R(t) = D \sin(sq) \sin(\omega_s t)$$

where:

$R(t)$	= Range variation	m
D	= Antenna radial offset	= 0.434 m
λ	= wavelength	= 0.125 m
sq	= squint angle	radians
ω_s	= spin rate	radians/s
t	= time	sec

In words: "Range fluctuates sinusoidally due to the spinning antenna by an amount $D \sin(sq)$ at spin rate ω_s "

The resulting carrier phase variation $\phi(t)$ is given by:

$$\phi(t) = 2 \pi R(t) / \lambda \quad \text{radians}$$

Now frequency is the rate of change of phase, so the carrier frequency variation $F(t)$ is:

$$F(t) = D/\lambda \omega_s \sin(sq) \cos(\omega_s t) \quad \text{Hz}$$

Again, in words, "Frequency fluctuates sinusoidally at spin rate by an amount F_{amp} given by":

$$F_{amp} = D/\lambda \omega_s \sin(sq)$$

This can be rearranged to give:

$$sq = \arcsin(F_{amp} / (\omega_s D / \lambda))$$

Since we know ω_s , D , and λ , by measuring F_{amp} we can determine squint directly.

Further, the absolute maximum deviation occurs at a squint of 90°, and is given by $D/\lambda \omega_s$. Call this F_{max} . Then for a given spin rate:

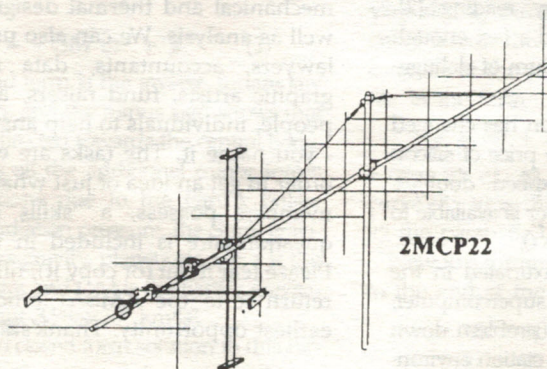
$$sq = \arcsin(F_{amp} / F_{max})$$

To put some numbers to this, at a squint of 30° and a spin rate of say 30 rpm., the FM amplitude is 10.9 Hz peak-peak.

Detector

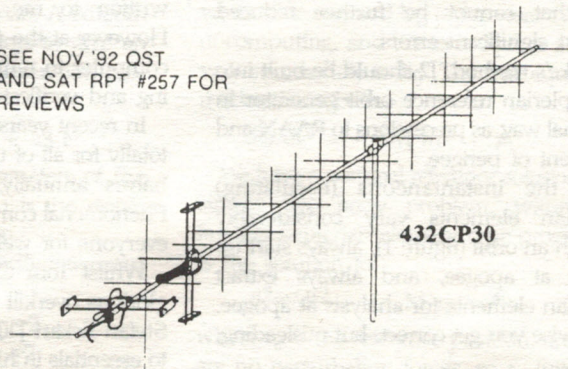
So much for theory. The next problem is how to build a detector. This is very easy. A PLL (phase locked loop) will track the variations of a carrier. Monitor its VCO voltage,

QUESTIONS AND ANSWERS (COMMONLY ASKED)



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3. What is the best element orientation for CP Yagis?
4. Can I mount two 436CP30s inside my two 2MCP22s?
5. Does the 2MCP22 absolutely need a vertical boom support?
6. Why doesn't M2 provide a RHC LHC switching unit?
7. Should I use a preamp with my OSCAR system?
8. Should I mount the preamp at the antenna?
9. Can I mount my OSCAR system up at 70 ft. above my HF Yagis?
10. What is the minimum clearance to the roof when I elevate the array?
11. What kind of feedline do you recommend?
12. Can I use my OSCAR system for terrestrial SSB/CW or FM?
13. Why should I buy the 2MCP22 when the 2MCP14 will hear the OSCAR?

If you still have questions, We will be glad to chat with you further. That is how we add even more value to the finest antennas on the market!

ANSWERS

1. To avoid cutting the circular field that surrounds a CP antenna and disturbing the pattern and VSWR, the feed line should come off the rear.
2. Yes, Metal tubing supporting coax will have little effect on performance.
3. Any mounting works but for easiest feedline routing, the X shape works best.
4. No because the 2m antennas act like a shield and 70cm antennas suffer.
5. No, only in heavy ice conditions, otherwise it is optional.
6. We have gone for reliability by eliminating a major loss and failure area.
7. A preamp will usually improve your signal to noise ratio on 2m and 70cm.
8. For feedlines over 50 feet, antenna mounted preamps are recommended.
9. Yes but for mechanical and maintenance reasons it is not recommended.
10. The reflectors should clear the roof by 4 to 6 inches.
11. Don't Skimp here. Hardline is best but 9913 is the best bang for the buck.
12. Absolutely! and CP is sometimes very helpful on terrestrial paths.
13. You will be able to hear the 'weak ones' with the larger 2MCP22.

More detailed answers are available by phone or FAX. We could probably write a book on CP antennas!

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and you will necessarily see the frequency variations converted to voltage fluctuations, which can be read off a 'scope. Anyone who has a PSK demodulator, either 400 bps or 1200 bps already has a carrier VCO system! A suitable PLL chip is the CD4046.

Proof of Concept

The good news is, it works! If you monitor the S-band beacon, it always has a little FMing on it. Previously one had assumed that this was due to fluctuations in battery voltage induced by spin or AGC effects. Not so! The explanation is as given above.

Assiduous telemetry readers or even transponder hackers may have noticed the S-band system was switched on at odd times during December 1992. This was to enable calibration to take place.

Sure enough, at a squint of 90°, the FMing is maximized at about 21 Hz peak-peak. Amazingly, though the high gain S-band antenna was by definition sideways on, admittedly at a range of only 10,000 km, there was a clear return on my 60 cm dish. Freddy ON6UG assisted in these tests, at considerable personal inconvenience, using his 2m dish and a pen recorder. Could you have got up at 3 a.m. several nights running to do this? A very big thank you to Freddy!

Figure 1 shows a typical output from my own processing software. Rather than manually read the voltage off a 'scope (very tedious), I connected the PLL VCO voltage directly to the ADC card of my computer and read the value that way at a rate of 100 samples/sec. Once the data is captured in a computer, it is infinitely easier to manipulate.

Lost In Space!

There is an interesting twist to this development, since it enabled the command stations to determine AO-13's attitude recently when the conventional methods had, for the first time, completely failed to converge to a solution. This was a potentially embarrassing situation to be in, as another attitude reorientation was imminent, and it is a good idea to know the current attitude before moving to another!

The situation was this. A routine attitude change from Alon/Alat 180/0 to 210/0 took place at the end of November 1992. This is a move of 30°, and we know that it can be accomplished by the magnetorquers in 4 perigee passes. We also know that re-orientation is somewhat erratic, but 4 perigees activity cannot move us more than 30°, so the change was bounded and safe (from the point of view of solar power production). This indeed proved to be the case, with a new safe attitude achieved, and the solar illumination essentially as planned.

However we also knew in advance that immediately after the change the Earth sensors would be blinded by the Sun for two weeks.

So we would have no reliable attitude measurements straight away. We would have to wait a few days for an accumulation of Sun data only.

Directly after the change, we realized that

we had experienced one of the random walks that the AO-13 magnetorquing process sometimes presents us. During mode-L and mode-S transponder operation, the spin modulation was found to be appalling. Even

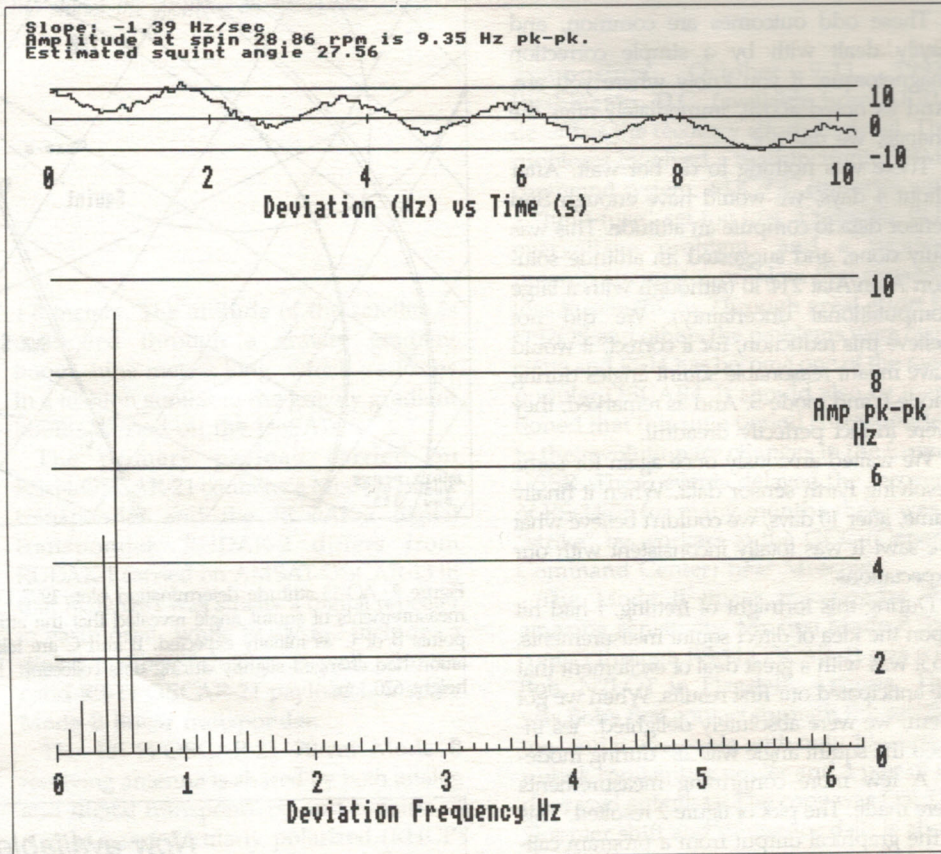
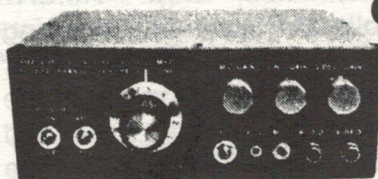


Figure 1. Oscar-13 Mode-S Transponder FM characteristics. Steady carrier uplinked, and PLL VCO voltage displayed. Fourier transform aids analysis. Steady slope is normal doppler shift vs. time. Data collected 1992 Dec 10 @ 2355 utc from location 52N 0E.

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the mode-B transponder was a relatively hard slog, and at only 25,000 km. My calibrated "golden" ears told me that the squint angle was 30° or more, which suggested the orientation was perhaps 20°-30° off the planned direction.

These odd outcomes are common, and easily dealt with by a simple correction magnetorquing, if you know where you are. And as noted above, immediately after the change, we did not.

There was nothing to do but wait. After about 4 days, we would have enough Sun sensor data to compute an attitude. This was duly done, and suggested an attitude solution Alon/Alat 214/10 (although with a large computational uncertainty). We did not believe this reduction, for if correct, it would have meant reasonable squint angles during mode-L and mode-S. And as remarked, they were in fact perfectly dreadful.

We waited anxiously once again for some resolving Earth sensor data. When it finally came, after 10 days, we couldn't believe what we saw! It was totally inconsistent with our expectations.

During this fortnight of fretting, I had hit upon the idea of direct squint measurements. So it was with a great deal of excitement that we anticipated our first results. When we got them, we were absolutely delighted. Yes indeed the squint angle was 28° during mode-S! A few more confirming measurements were made. The plot of figure 2 resulted. This is the graphical output from a program called ATTIPLOT that is used to determine AO-13 attitude from multiple sensor observations. Our conclusion was that the attitude direction was in fact Alon/Alat 196/27, marked as point A. Hardly the planned value of 210/0!

The important thing about this plot is that, under normal circumstances, all data lines should intersect at one point. That is, the three Sun lines, the upper and lower Earth sensor lines, and the two Squint lines should converge at 196/27.

That they do not is, with 100% hindsight, because a) the lower Earth sensor was giving invalid data at the time, and b) what we have long suspected, the spin axis direction sometimes wanders due to buffeting during its low perigee encounters. That's why the Sun sensor data doesn't converge at A but gives falsies B and C.

That the Squint lines, upper Earth sensor and newest Sun line do intersect properly at A is regarded as a triumphant success for this new method. Furthermore, the next attitude change in 1993 January was planned using this determination, and executed perfectly. Imagine what would have happened if the seductive solution C had been adopted! ■

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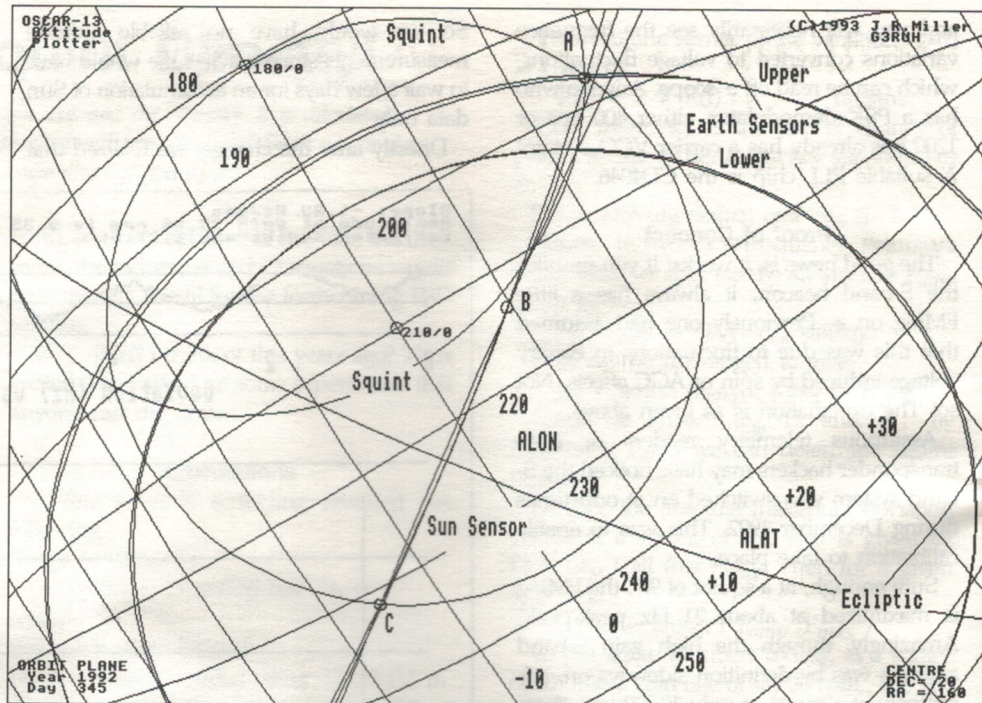


Figure 2. AO-13 attitude determination plot, 1992 Dec 10. This shows graphically how direct measurements of squint angle revealed that the attitude direction was given by point A, and not points B or C as initially expected. B and C are false solutions because unusually the spin axis orientation had changed slightly during data collection. Probably caused by buffeting during perigee fly-by, height 620 km.

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Spotlight On: RS-14/OSCAR-21

[This article is the latest in a continuing series of articles covering currently active Amateur Radio satellites. In this issue of *The AMSAT Journal*, KD2BD shines the spotlight on RS-14/OSCAR-21.]

By John A. Magliacane, KD2BD
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Spacecraft History

RS-14/OSCAR-21 was launched on January 29, 1991 from the North Cosmodrome at Plesetsk, Russia on a Proton rocket along with the INFORMTR-1 satellite and Russian GEOS geological research satellite to which it is attached and from which it receives its power. RS-14/OSCAR-21 is a cooperative effort between the AMSAT-U-Orbita and AMSAT-U-Sputnik groups in Russia, and the RUDAK group of AMSAT-DL in Germany. The official name of this satellite is RADIO M-1 (RM-1). After successful launch, the satellite was given the name AMSAT-OSCAR-21 in recognition of the international cooperative effort in building and launching the satellite. It is a continuation of both the Radio Sputnik (RS) series, as well as the AMSAT-OSCAR series of Amateur satellites.

The orbit of RS-14/OSCAR-21 is that of low altitude, high inclination, and near circular, which is typical of RS and Phase 2 OSCAR satellites. Although RS-14/OSCAR-21 contains a myriad of flexible analog and digital operating modes, the satellite is primarily a Mode B satellite, with uplinks in the 70-cm band, and downlinks in the 2-Meter band. RS-14/OSCAR-21 carries two Amateur communications payloads with two Mode B linear transponders and a digital transponder capable of no less than eight downlink modes, all of which are under the control of a Harris RTX2000 RISC (Reduced Instruction Set Computer) and DSP (Digital Signal Processor) hardware.

RS-14/OSCAR-21 was the first Amateur spacecraft to successfully carry out RUDAK (Regenerativer Umsetzer fur Digitale Amateurfunk Kommunikation) operations from earth orbit, with AMSAT-OSCAR-13's RUDAK-1 transponder having failed after launch.

RS-14/OSCAR-21 System Specifications

The physical structure of RS-14/OSCAR-21 is that of a cylinder having a height of 4 meters and a diameter of

1.8 meters. The attitude of the satellite is controlled through a gravity gradient boom, nine meters long, which performs in a fashion similar to the gravity gradient booms carried on the UoSATs.

The primary payload carried on RS-14/OSCAR-21 contains a Mode B linear transponder and the RUDAK-2 digital transponder. RUDAK-2 differs from RUDAK-1 carried on AMSAT-OSCAR-13 in that RUDAK-1 was strictly a digital repeater in earth orbit, while RUDAK-2 includes a digital mailbox function as well. The second RS-14/OSCAR-21 payload is a spare Mode B linear transponder.

The RS-14/OSCAR-21 70-cm Mode B receiving antenna is shared by both analog and digital transponders, and consists of a right hand circularly polarized (RHCP) helix with +3 dB of gain. The 2-Meter RS-14/OSCAR-21 downlink antenna is a linearly polarized half wave dipole antenna with unity gain.

Mode B Operations

After successful initial tests RS-14/OSCAR-21 began to experience problems in March 1991 and it was not until May 1992 that regular operations became possible. An article by DB2OS in the Proceedings of the Tenth Amsat-NA Space

Symposium, October 9-11, 1992, Washington, D.C. (available from ARRL) describes the recovery efforts in detail. The problems involved a malfunctioning RM1 command system, a DC/DC converter with a "limit fuse" set too low, a possible BUS overvoltage problem, and a receiver preamp attenuator problem that caused a loss in sensitivity. Through great effort by DB2OS and others the problems were overcome and RS14 has become one of the most popular OSCARs. It should also be mentioned that this time period corresponded to the revolutionary changes in the former USSR. These events delayed the recovery of RS-14 as for many months there was a "strike" by workers at the GCC (General Command Center) near Moscow.

The Mode B linear transponder has amazing sensitivity. My first Mode B SSB contact through RS-14/OSCAR-21 was with Bob, N7LQT in Flagstaff, Arizona. That was Bob's first contact through the satellite too, and it was made with only 10-watts of uplink transmitter power and a pair of indoor yagi antennas. The copy was Q5! The Doppler shift and frequency drift is about the highest that can be experienced among any of the currently active Amateur satellites, so it takes some getting used to.

A CW telemetry beacon can usually be heard coming from RS-14/OSCAR-21. The frequency of the beacon is dependent on what transponder is currently active. In addition to Morse telemetry, a digital beacon may be heard transmitting in any number of modes. The digital beacon is under control of the RUDAK-2 payload and has amazing flexibility.

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RS-14/OSCAR-21 has a total of four digital transponder I.F. amplifiers and as many data demodulators. Included are a 1200 bps FSK demodulator, a 2400 bps BPSK demodulator, a third for 4800 bps RSM-PSK (Rectangular Spectrum Modulation) operations, and one 9600 bps RSM-PSK uplinks. RSM is a form of BPSK that concentrates 99.9% of the transmitted spectral energy within a bandwidth of 1.5 times the data bit rate. A fourth uplink receiver is coupled directly to DSP hardware for demodulation using Digital Signal Processing techniques. RS-14/OSCAR-21 is an excellent platform for development and testing of new radio modem designs. The DSP demodulator and flexible software control make the satellite extremely accommodating in its ability to handle different

modulation techniques and transmission speeds on its various uplinks.

OSCAR-21 Speaks!

In addition to providing analog and digital communications service, RS-14/OSCAR-21 is also capable of transmitting speech through its DSP hardware. Various voice messages from the satellite's controllers have been digitized, uplinked to RS-14/OSCAR-21, and later transmitted by the satellite through one of its downlink transmitters.

An FM Repeater In Space

Most recently, RS-14/OSCAR-21 has been spending a good portion of its time in an FM repeater mode, where FM signals received on an uplink frequency of 435.016 MHz are relayed on a downlink frequency

of 145.983 MHz. This has allowed many satellite enthusiasts without SSB, CW or digital communications capabilities to experience satellite communications with low-cost FM ground station transceivers. Since the FM transponder has only a single uplink and single downlink frequency, contacts are usually very short in duration, and sound like 10-Meter FM contacts made through the W2IBJ/R repeater on the island of Saint Thomas in the Virgin Islands. 145.983 MHz has become the world's first "party line" with other satellite communicators. Its 3 watt downlink signal is quite strong, so it can be easily received with a handheld receiver or transceiver and a minimal antenna.

Summary

Even though it has been two years since its launch, RS-14/OSCAR-21 is still undergoing tests by its controllers. No formal transponder operating schedule has been announced, and the satellite can be in any one of its operating modes at any time. But that does not limit the satellite's usefulness in any way.

So try tuning in RS-14/OSCAR-21! You might be pleasantly surprised by what you hear coming from this versatile satellite.

Next time, we'll shine the spotlight on the KITSAT/OSCAR-23 spacecraft! ■

TABLE 1 RS-14/OSCAR-21 Catalog Number: 21088

Primary Payload

Beacons and Telemetry #1

CW Telemetry (8 Channels)	145.822 MHz 0.2 Watts
Digital Telemetry (30 Channels)	145.952 MHz 0.4 Watts
	1100 bps, BPSK/FM, 2 KHz deviation
Digital Telemetry RUDAK-2	145.983 MHz 3.0 Watts
	BPSK 1200 bps NRZI, AX.25 (Like Pacsats)

Transponder #1: Mode B - Linear, Inverting

Uplink Passband	: 435.102 MHz to 435.022 MHz
Downlink Passband	: 145.852 MHz to 145.932 MHz 10 Watts Maximum
Uplink EIRP	: 100 Watts

RUDAK-2 Digital Transponder

This transponder supports AX.25 digital repeater communications in addition to packet radio store and forward mailbox operations with a 1 Megabyte RAM disk and four uplink channels.

Uplink Frequencies	: RX-1 435.016 MHz 1200 bps, FSK, NRZIC/Bi-Phase-M
	RX-2 435.155 MHz (AFC) 2400 bps, BPSK, Bi-Phase-S
	RX-3a 435.193 MHz (AFC) 4800 bps, RSM
	RX-3b 435.193 MHz (AFC) 9600 bps, RSM
	RX-4 435.041 MHz (Digital AFC) RX for RTX-DSP

Downlink Frequency : 145.983 MHz 3.0 Watts

The downlink can be switched to any one of the following modes:

Mode 1	: 1200 bps, BPSK, NRZI (NRZ-S) (Like FO-20 and the Pacsats)
Mode 2	: 400 bps, BPSK, Bi-Phase-S (Like AO-13 Beacon)
Mode 3	: 2400 bps, BPSK, Bi-Phase-S
Mode 4	: 4800 bps, RSM, NRZIC (Bi-Phase-M) (Like the 4800 bps uplink)
Mode 5	: 9600 bps, RSM, NRZI (NRZ-S) + Scrambler (Like 9600 bps uplink)
Mode 6	: CW Keying (for special events only)
Mode 7	: FSK (F1 or F2B), e.g. RTTY, SSTV, FAX, etc. (for special events)
Mode 8	: FM Modulated by D/A signals from the DSP-RISC processor (speech)

TABLE 2 Secondary Payload

Beacons and Telemetry #2

CW Telemetry (8 Channels)	145.948 MHz 0.2 Watts
Digital Telemetry (30 Channels)	145.838 MHz 0.4 Watts
	1100 bps, BPSK/FM, 2 KHz deviation
Digital Telemetry RUDAK-2	145.800 MHz 2.0 Watts
	1100 bps, BPSK/FM, 2 KHz deviation

Transponder #2: Mode B - Linear, Inverting

Uplink Passband	: 435.123 MHz to 435.043 MHz
Downlink Passband	: 145.866 MHz to 145.946 MHz 10 Watts Maximum
Uplink EIRP	: 100 Watts

TABLE 3

"RUDAK-2 BPSK 1200 bps AX.25 downlink copied by KD2BD on 12-Jun-92."

```
RUDAK> BEACON <UI C> :
* RUDAK-II / AMSAT OSCAR 21/ RM1
* Up: 435.016MHz (1200)
* 435.155MHz (2400)
* Mailbox=RUDAK Mheard=RUDAK-1
```

```
RUDAK> EPROM <UI> :
RUDAK-2 EPROM-Test
```

```
RUDAK> BEACON <UI C> :
RUDAK-Telemetry (09-06-12 20:46:00):
Used stack entries: 0
Uplink Carrier Detect (during last minute): 0%
```

```
RUDAK> BEACON <UI C> :
* RUDAK-II / AMSAT OSCAR 21/ RM1
* Up: 435.016MHz (1200)
* 435.155MHz (2400)
* Mailbox=RUDAK Mheard=RUDAK-1
```

```
RUDAK> EPROM <UI> :
RUDAK-2 EPROM-Test
```

```
RUDAK> BEACON <UI C> :
* RUDAK-II / AMSAT OSCAR 21/ RM1
* Up: 435.016MHz (1200)
* 435.155MHz (2400)
* Mailbox=RUDAK Mheard=RUDAK-1
```

```
RUDAK> EPROM <UI> :
RUDAK-2 EPROM-Test
```

```
RUDAK> BEACON <UI C> :
* RUDAK-II / AMSAT OSCAR 21/ RM1
* Up: 435.016MHz (1200)
* 435.155MHz (2400)
* Mailbox=RUDAK Mheard=RUDAK-1
```


TABLE 4

"RUDAK-2 AFSK-FM 1200 bps AX.25 downlink copied by KD2BD on 13-Dec-92."

```

RUDAK2> TLM-2 <UI C> :
5V-RAM: 4.95 V      3-RNG : ON      AGC
Total Current      4-Soft: 0.2 V    RX3: 147    Temperature
14V-I : 312 mA      RX4: 204      27.2 deg C

RUDAK2> BEACON <UI C> :
RUDAK-II Schedule:      Downlink 145.987
UTC (Min. MOD 10)      Beacon Mode      Uplink/MHz
0...5                  FM Repeater      435.016
6...8                  Digital Voice      no
9                      AFSK Telemetry      no

RUDAK2> BEACON <UI C> :
Slovenian Message:
Hi, this is RUDAK-II on the satellite RS 14.
Greetings to all, to MATJAz best wishes
for his convalescence

RUDAK2> BITFAT-1 <UI C> :
RUDAK2> BITFAT-2 <UI C> :
RUDAK2> BITFAT-3 <UI C> :
RUDAK2> BITFAT-4 <UI C> :
RUDAK2> EPROM <UI C> :
RUDAK-2 EPROM-Test

RUDAK2> BEACON <UI C> :
++ Hi, this is the RUDAK-II experiment on AMSAT OSCAR 21 ++

RUDAK2> TLM-1 <UI C> :
RUDAK-II Telemetry (92-12-13 00:19:12):
Voltages      RM1-TCMD-Interface      Lock      Memory Errors
5V-R1 : 0.80 V      1-TX-ON : OFF      RX2: *      Single: -122
5V-RTX: 5.02 V      2-RX12&48: OFF      RX3: -      Multi : 0

RUDAK2> TLM-2 <UI C> :
5V-RAM: 4.95 V      3-RNG : ON      AGC
Total Current      4-Soft: 0.2 V    RX3: 145    Temperature
14V-I : 318 mA      RX4: 204      27.2 deg C

RUDAK2> BEACON <UI C> :
RUDAK-II Schedule:      Downlink 145.987
UTC (Min. MOD 10)      Beacon Mode      Uplink/MHz
0...5                  FM Repeater      435.016
6...8                  Digital Voice      no
9                      AFSK Telemetry      no

RUDAK2> BEACON <UI C> :
Slovenian Message:
Hi, this is RUDAK-II on the satellite RS 14.
Greetings to all, to MATJAz best wishes
for his convalescence

```

AMSAT QSL Bureau

Rules for using the AMSAT OSCAR QSL Bureau.

1. The AMSAT QSL Bureau serves the users of all Amateur Radio Satellites with a complete QSL Bureau for all Amateur Radio satellite contacts (QSLs other than satellite QSOs will be returned).
2. Stations wanting to use the Bureau; arrange your cards ALPHABETICALLY by call sign. Stateside cards are free. However there is a charge of 5 cents per card for all stations outside US Postal districts.
4. Always keep the Bureau informed of any changes in your address or call sign. If you have worked stations using more than one call sign, you should send envelopes for both call signs.
5. Mailings from the Bureau will be at the end of each month. All envelopes with ANY cards will be mailed at this time. The only exception is if the Amateur would like to have his/her envelope held for a certain amount of cards before being mailed. This can be done by writing just below your call sign (in the upper left hand corner) the number of cards desired in the envelope before it is mailed.
6. QSL cards that are received at the Bureau when there are no envelopes on file will be held and the Bureau will make an attempt to notify the user that he/she has cards on file. If no envelopes are sent to the Bureau within a period of 6 months, the cards will be destroyed!
7. Mailings for DX stations and individual international QSL Bureaus will go out at the end of the month.
8. Any questions about the Bureau should be sent with an SASE to the QSL Bureau Office. ■

Perry Yantis, WB8OTH

AMSAT QSL Bureau Manager

AMSAT-NA QSL Bureau

1850 Lisle Ave.
Obetz, OH 43207



Top Prizewinner at the Annual Meeting

Marjorie Swain of Kent, Washington wins the top prize at the AMSAT Annual Meeting held at Intelsat Headquarters in Washington, DC in mid October. Marjorie is the XYL of Carroll Swain W7DU, who was very happy that his wife came away with the Kenwood TS-751 multimode 2 meter transceiver which he expects to put to good use in his satellite station. The unit was kindly donated by Kenwood U.S.A.

Heard on the Downlink

By: John Hansen, WA0PTV
AMSAT Journal Assistant Editor

Welcome to what we hope will become a regular feature in the AMSAT Journal. This space will regularly contain a compendium of information that is either useful, interesting, or both. It will contain tips on establishing and improving satellite groundstations, new ideas to try out on the birds and information about recent amateur satellite developments. By and large it will deal with topics and issues that are too brief to warrant treatment as full-blown articles in the Journal, but are important nonetheless.

In a very real sense, this space is your space. Send in your own tips, remembering that there are a significant number of AMSAT members who have never actually had their signals on one of the birds and are looking for assistance. Also, send in your questions. If I can't answer them I can find someone who can. With the introductions out of the way, here is this issue's potpourri.

9913 Coax Sucks Water

Many, if not most satellite operators are using Belden 9913 (or equivalent) coax for feedline. It is significantly cheaper than hardline, but has significantly lower losses than RG-8, RG-213, etc. I've used it for years and it is a good quality product. However, it is extraordinarily easy to have it completely destroyed by water. If you cut a piece of this stuff open you will find that there is a considerable space filled with air inside. Given that air is a low loss dielectric (remember the low losses associated with open wire feeders?), this is probably not surprising. As the air in 9913 coax heats up, it expands, blowing air out any possible opening in the line or connectors. As it cools the air contracts pulling air from the atmosphere back inside. Now the problem comes if the coax and connectors are not air-tight and there is moisture on the outside. Whatever moisture there is will be sucked inside along with the air. Since it is the cooling that causes this, the coax most often goes bad with the advent of cold, wet weather, just when its hardest to replace. You may also find that it deteriorates slowly over time so that you don't notice what's going on until it drops out altogether.

It is not adequate to simply make sure that the connectors are firmly sealed onto the coax. When I first put up a KLM 22C for satellite use, I was amazed one day when I disconnected the feedline at the transceiver and water streamed out and formed a puddle on my operating desk. No wonder signals were

down! I knew that I had gone to great lengths to make sure the connector at the antenna was well sealed to the line, so what happened? Well, it turned out this sucking action had actually pulled water through the female coax connector on the antenna and into the feed line. The moral of this story is to seal the back of the connector that you are plugging the 9913 into as well as the connector on the feedline itself.

Duct Seal

To do this kind of sealing, I no longer use standard Coax Seal. That stuff works just fine, but it seems to be awfully expensive. Most of the folks that I know go down to the local electrical supply house and buy some stuff called "Duct Seal". It is a grey putty-like substance that does a very good job of sealing coax connections. It costs about \$2.50 a pound. It is, however, much stiffer than coax seal and you have to work it in your hands

like clay to get it to loosen up to the point where it is pliable enough to put on the connections. This is especially hard to do in cold weather when it gets to be almost rock hard. Last week I was confronted with this situation and decided to put it in a microwave oven to warm it up before I went to the roof to install a new feedline for my 70 cm. antenna. About 1.5 minutes on full power did the trick and it was a joy to use, even in the cold weather.

Inside Information Department

I have had correspondence recently from the folks at BY1PK in Beijing that leads me to believe that they may well be active quite soon on AO-13 or other satellites. Watch for ops BZ1AA or BZ1HAM operating from the CRSA station BY1PK, perhaps even by the time you read this.

If anyone hears these guys on, I would appreciate it if you would drop me a note with the time and date of the QSO.



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Getting Your Directory Up-To-Date on Uo22

Seems I'm always hearing people complain that there are so many files on Uo22 (especially gateway files) that they can never get a complete and up-to-date directory. First of all, the gateway system has taken substantial steps toward reducing the number of files on the satellite. On the other hand I almost never have trouble getting a directory from the bird and I think that others might also find the directory was a minor problem if they made a few changes in their operating habits.

The problem of getting an up-to-date directory stems from the view that the most efficient way to operate the satellite is first to get a directory of the files on it, then figure out what files are of interest, and then request those files. NOT! If you take this approach, given the current levels of loading on Uo22, you may never complete step one (getting the directory).

Try this approach instead. Let's suppose you are starting a pass in which you do not have a complete directory, but (for the sake of argument), there are no files in your most recent directory that you are dying to have and have marked for broadcast. So go ahead and let your system accumulate directory entries. It will do this for you directly if you are lucky enough to avoid the "-1" and get a slot on the que, otherwise you will accumulate directory entries as you eavesdrop on the directory requests of others. From time to time use the "V" key to see what you've accumulated and look for things that might be of interest to you. When you spot one (or more) you want, mark it (or them) for broadcast (P or A) and go back to the main screen. You will note that your system is still requesting a directory. Hit Cntl-A twice and the bottom of your screen will indicate that you are now looking for the file you asked for. This may be an illusion, however, as if you are still on the satellite que looking for a directory, it will continue to do so until it gets the directory. To prevent this, hit the F key and type the number of the first file that you requested. The automatic system will then take over and begin requesting that file (and any others you have marked). But you will still continue to get directory entries based on the directory requests of other users. Let them take care of your directory requests for you, you can stay reasonably well up-to-date on the directory without ever issuing a directory request yourself.

If, on the other hand, at the start of the pass there are files you have already marked for broadcast, don't worry if your directory is falling behind. It will catch up reasonably well based on the directory requests of others. Just don't let it bother you if there are parts that you are missing.

I run a satellite gateway and gateway node station, so staying up to date on the directory is very important to me. On average, however, I don't actually request a directory from the satellite more than about once a week. I see "Up-to-Date" on my system fairly frequently, but if I don't see it for days I don't worry either. The directory will come along, based on the requests of others.

While on the subject of the digital satellites, if you are looking for a program that integrates PB, PG, a header adder and stripper, an editor of your choice, and file management capabilities, check out SafTerm, a package available on Uo22 or by sending a disk and return mailer to the address at the bottom of this column. Sometimes the best things in life really are free.

NK6K in QEX

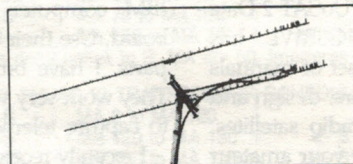
Has anyone else noticed that Harold Price, NK6K has recently started an every other issue column in QEX, the ARRL's publication for experimenters? There are a number of excellent satellite columnists in the various amateur magazines, but I mention Harold in this space because he has contributed great-

ly to the amateur satellite program by being instrumental in the design and execution of the Pacsat and UoSat software, including the broadcast protocol. In his first QEX column, NK6K hinted at the development of a terrestrial broadcast protocol, something which in my judgment would be an enormous contribution. I contacted Harold about it... nothing in the works currently, but a lot of thinking going on.

CQ Productions Video

CQ Productions has new series of video tapes out and one is a 45 minute introduction to satellite operation. This tape is not geared toward non-hams, but rather is geared toward hams who have had little or no exposure to satellite operation. It is quite well done, and would be an excellent program for your local ham club meeting. It features about 5 minutes of video from a tape the local college made of my hamshack during a Uo22 pass that shows how high speed gateways work. If you would like a copy of the CQ tape, contact CQ productions or its usual outlets. If you would like a copy of the Uo-22 video contact me directly. ■

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Hungry for additional satellite information?

By: G. Gould Smith
8008 Chesterfield Drive
Knoxville, TN 37909
WA4SXM @KT4FTN.USA
CompuServe 72067,757

One of the most pleasant surprises at the 1989 AMSAT Symposium in Des Moines was meeting Ron Broadbent, G3AAJ. Besides being quite an interesting fellow to talk with, he is a tireless AMSAT volunteer. Ron introduced me to a treasure trove of information that AMSAT-UK makes available. Ron had brought a few PC boards for the G3RUH 400 bps PSK telemetry demodulator with him to the symposium. I had been curious about the information that was being transmitted on the AO-13 beacon and jumped on one of these reasonably priced boards. He also gave me a sheet of paper listing the AMSAT-UK 'Services to Members'. I just filed it with my other symposium literature. Reviewing this sheet after returning home, I was amazed to find publications available for many of the things in which I had a interest, but had been unable to find information about here in the US.

My first order to AMSAT-UK was for: the set of technical manuals on Mir, OSCAR-13, RS-10/11 and FO-12; and the "UoSAT 2 Data Booklet". RWL Limebear, G3RWL has assembled a very fascinating set of manuals describing the history, hardware, design and operation of these amateur radio satellites. These manuals are a must for your amateur satellite library. Since non-members must pay an extra 20%, I decided to join AMSAT-UK.

Another jewel in the crown came when I received my first issue of "OSCAR NEWS", the AMSAT-UK amateur satellite journal. These bi-monthly journals are full of interesting articles and give a continental view of amateur satellite programs. Ron's 'Waffle Pages' at the end of each issue are direct and timely. I enjoy reading information that is to the point; Ron makes his position clear. James Miller manages to make many complex subjects understandable, and Chris V. den Berg provides behind the scenes information on the Mir space station. Remember, AMSAT is a group of international organizations. Your membership and publications donations go toward keeping all the amateur satellite programs moving, like the design and building of Phase 3D.

The Colloquium Proceedings were my next find. Papers from the famous Surrey meetings are available from 1988-1992. These certainly complement our own AMSAT-NA Symposium Proceedings. If you don't have and

READ these papers you are missing out on a great deal of important amateur satellite information. The papers contain useful information that is historical as well as current. I still refer to my older editions as my interests change or if I am looking for an answer to a specific question. More often than not I get side-tracked with another article I run across while looking for a different one. I have finally figured out that there is usually a very good historical and logical reason for the way most things in amateur satellites are today. Many things that appear as bad decisions today, when reviewed with the information and resources available at the time that the decisions had to be made, appear much differently. Read about the development of the satellites and learn why things are the way they are.

For the builders among us, beside the AO-13 400 bps circuit boards, AMSAT-UK offers the G3RUH 1200 bps PSK board, the G3RUH UoSat-2 demodulator board and an IBM computer based antenna controller board. Use their board and supply your own parts. I have built-up two of these boards. They work very well and I am still using them to capture telemetry.

I recently received an excellent, inexpensive booklet from AMSAT-UK entitled "Orbital Mechanics and Satellite Terminology" by Bob Phillips, G4IQQ. In fourteen pages Bob diagrams a description of the Keplerian terms used by the tracking programs to determine a satellite's orbit. These diagrams describe things much better than could be done in one thousand words each.

Tracking software and telemetry decoding software not available in the US is available from AMSAT-UK. One of them just might contain that feature that you need, but heretofore not been able to find.

Mike Crisler phrased a feeling that I have had, "What AMSAT has to sell is information". A small number of AMSAT members contribute many hours designing, building, describing and maintaining the amateur satellites that so many of us use. If we cannot directly participate in the processes of the physical satellites themselves, we can learn as much as possible about them and their operation. This knowledge can then be passed along to others or to help us find a place to contribute to the effort. We have asked too

much of too few, we need to provide a backup and relief corps. Take advantage of all the available material and make yourself more knowledgeable and a contributor to the amateur satellite program. If you aren't the inquisitive type, you can still obtain these publications and pass them on to some younger people, to schools or to libraries.

AMSAT-UK offers a great many services to its members and to the entire amateur satellite community. Membership is even open to us on this side of the pond. You will be pleasantly surprised by the wealth of material that AMSAT-UK can provide. You are missing a great opportunity by not taking advantage of their offerings.

If you send me an SASE and request the current AMSAT-UK offerings I will send you a copy of the latest list of the services to AMSAT-UK members.

For more information about AMSAT-UK you may contact the Hon. Secretary, Ron Broadbent for membership information and services at:

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Call for Articles:

The AMSAT Journal is a compilation of material submitted by AMSAT Members. The AMSAT Journal is always looking for new material. If you have a project you have been working on - let us know about it. Just as you have benefited from the the experiences of others, let others benefit from your experiences. Look on Page 3 for details describing how to submit material to the Editorial Office. ■

AO-13 Provisional Attitude Schedule 1993-4

by James Miller, G3RUH

Date	[Mon]	Alon/Alat	Modes	SA to SA	
1992	Dec 14	210/0	B	-28	-36
	via 180/15 to				
1992	Dec 21	130/0	B	-43	-35
1993	Jan 04	140/0	B	-45	-34
1993	Jan 18	150/0	B	-45	-27
1993	Feb 08	150/0	BJLS	-27	-3
1993	Mar 08	180/0	BJLS	-32	+33
1993	May 10	210/0	BJLS	+11	+33
	via 180/15 to				
1993	May 31	120/0	B	+41	+34
1993	Jun 14	130/0	B	+43	+35
1993	Jun 28	140/0	B	+45	+36
1993	Jul 12	150/0	B	+45	+30
1993	Aug 02	150/0	BJLS	+30	+5
1993	Aug 30	180/0	BJLS	+28	-26
1993	Oct 18	210/0	BJLS	-7	-29
	via 180/15 to				
1993	Nov 08	120/0	B	-43	-34
1993	Dec 06	130/0	B	-44	-36
1993	Dec 20	140/0	B	-45	-36
1994	Jan 03	150/0	B	-45	-32
1994	Jan 17	150/0	BJLS	-32	-11
1994	Feb 07	180/0	BJLS	-27	+29
1994	Mar 28	210/0	BJLS	+12	+32
	via 180/15 to				
1994	Apr 18	120/0	B	-43	-34 etc

AQ-13 Provisional Mode Schedules 1993-4

M QST *** AO-13 TRANSPONDER SCHEDULE *** 1992 Dec 21 - Feb 08
 Mode-B : MA 0 to MA 256 !
 Mode-S : MA !
 Mode-LS : MA ! Attitude Dec 21 130/0
 Mode-JL : MA ! Jan 04 140/0
 Mode-B : MA ! Jan 18 150/0
 Omnis : MA 170 to MA 15 !
 Eclipses : Transponder OFF MA 170 to 256 Jan 28 - Mar 04

M QST *** AO-13 TRANSPONDER SCHEDULE *** 1993 Feb 08 - Mar 08
 Mode-B : MA 0 to MA 40 !
 Mode-S : MA 40 to MA 50 ! <- S transponder; B trsp. is OFF!
 Mode-LS : MA 50 to MA 55 ! <- S beacon + L transponder
 Mode-JL : MA 55 to MA 70 ! Alon/Alat 150/0
 Mode-B : MA 70 to MA 256 !
 Omnis : MA 170 to MA 15 ! Move to attitude 180/0, Mar 08
 Please don't uplink to B, MA 40- 50. Interferes with mode S.

M QST *** AO-13 TRANSPONDER SCHEDULE *** 1993 Mar 08 - May 10
 Mode-B : MA 0 to MA 120 !
 Mode-S : MA 120 to MA 130 ! <- S transponder; B trsp. is OFF!
 Mode-LS : MA 130 to MA 135 ! <- S beacon + L transponder
 Mode-JL : MA 135 to MA 150 ! Alon/Alat 180/0
 Mode-B : MA 150 to MA 256 !
 Omnis : MA 230 to MA 40 ! Move to attitude 210/0, May 10
 Please don't uplink to B, MA 120-130. Interferes with mode S.

M QST *** AO-13 TRANSPONDER SCHEDULE *** 1993 May 10 - May 31
 Mode-B : MA 0 to MA 180 !
 Mode-S : MA 180 to MA 190 ! <- S transponder; B trsp. is OFF!
 Mode-LS : MA 190 to MA 195 ! <- S beacon + L transponder
 Mode-JL : MA 195 to MA 210 ! Alon/Alat 210/0
 Mode-B : MA 210 to MA 256 !
 Omnis : MA 250 to MA 60 ! Move to attitude 120/0, May 31
 Please don't uplink to B, MA 180-190. Interferes with mode S.

M QST *** AO-13 TRANSPONDER SCHEDULE *** 1993 May 31 - Aug 02
 Mode-B : MA 0 to MA 256 !
 Mode-S : MA !
 Mode-LS : MA ! Attitude May 31 120/0
 Mode-JL : MA ! Jun 14 130/0
 Mode-B : MA ! Jun 28 140/0
 Omnis : MA 170 to MA 10 ! Jul 12 150/0

M QST *** AO-13 TRANSPONDER SCHEDULE *** 1993 Aug 02 - Aug 30
 Mode-B : MA 0 to MA 40 !
 Mode-S : MA 40 to MA 50 ! <- S transponder; B trsp. is OFF!
 Mode-LS : MA 50 to MA 55 ! <- S beacon + L transponder
 Mode-JL : MA 55 to MA 70 ! Alon/Alat 150/0
 Mode-B : MA 70 to MA 256 !
 Omnis : MA 170 to MA 10 ! Move to attitude 180/0, Aug 30
 Please don't uplink to B, MA 40- 50. Interferes with mode S.

M QST *** AO-13 TRANSPONDER SCHEDULE *** 1993 Aug 30 - Oct 18
 Mode-B : MA 0 to MA 120 !
 Mode-S : MA 120 to MA 130 ! <- S transponder; B trsp. is OFF!
 Mode-LS : MA 130 to MA 135 ! <- S beacon + L transponder
 Mode-JL : MA 135 to MA 150 ! Alon/Alat 180/0
 Mode-B : MA 150 to MA 256 !
 Omnis : MA 230 to MA 40 ! Move to attitude 210/0, Oct 18
 Please don't uplink to B, MA 120-130. Interferes with mode S.

M QST *** AO-13 TRANSPONDER SCHEDULE *** 1993 Oct 18 - Nov 08
 Mode-B : MA 0 to MA 180 !
 Mode-S : MA 180 to MA 190 ! <- S transponder; B trsp. is OFF!
 Mode-LS : MA 190 to MA 195 ! <- S beacon + L transponder
 Mode-JL : MA 195 to MA 210 ! Alon/Alat 210/0
 Mode-B : MA 210 to MA 256 !
 Omnis : MA 250 to MA 60 ! Move to attitude 120/0, Nov 08
 Please don't uplink to B, MA 180-190. Interferes with mode S.

Eclipses of Sun by Earth 1993 - Summary

Start	MA	Max	Mins	MA-MA	Stop	MA
1993 Jan 28	195	Feb 06	96	190-226	Mar 10	239
1993 Apr 09	250	Jul 20	24	253-006	Sep 12	003
1993 Dec 05	110	Dec 13	140	102-156	Dec 22	144
1994 Mar 19	254	May 23	23	251-004	Jul 20	001

Eclipses of Sun by Moon 1993 - Summary

Date	Duration	Obsc%	Orbit	MA-MA
1993 Jun 20	15	4	3841	223-229
1993 Nov 13	167	81	4148	169-204
1993 Dec 13	45	27	4211	72- 89
	mins			

Receiving Arsene on S Band

By: Ed Krome, KA9LNV
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The first French amateur spacecraft, ARSENE, is scheduled to be launched in April. It will contain two transponders. The first will be an AX.25 AFSK FM digital transponder (no mailbox) operating on Mode B (70cm uplink; 2m downlink). The second is an analog transponder with a 70cm uplink and an S band downlink. The S band downlink operates on 2446.5 MHz. All other amateur satellites that have an S band transmitters (AO13, PACSAT and DOVE) downlink near 2401 MHz. This frequency difference has caused concern over the suitability of common S band receiving equipment to the new satellite.

S Band Downconverters

The most common S band downconverter is the WA8NLC/KK7B design sold as both kit and ready-made by W3HQT at Down East Microwave. This unit is easy to build without test equipment (and works!) and makes extensive use of printed hairpin filters. The filters were designed to be very broad and steep skirted to allow a single design to be used on both 2304 MHz and 2401 MHz. They work extremely well. The nature of these filters begs the question: just how broad are they? And is there any way to make them operate almost 50 MHz above their design limit?

To answer these questions, I did some experimenting with my own unit. Fortunately, the results were quite satisfactory, although just barely.

Method 1: Vary the IF

The first method tried was to leave the converter in standard satellite S band configuration, with a 94 MHz LO crystal. Normal operation converts 2400-2402 MHz to 144-146 MHz. With a 2446.5 MHz input signal, the IF became 190.5 MHz, which would be receivable on a general

coverage VHF/UHF receiver such as the R7000. If the filters and ring mixer would allow it, of course.

Amazingly, the No-Tune converter did just fine at 2446.5 MHz in and 190.5 out! But that is right on the limit of the filters. At 2446 MHz, the unit is only 3-4 db down in performance from its performance on 2401 MHz. But go up to 2475 MHz, and the signals are over 20 db further down. The skirts on these filters are steep.

Method 2: Vary the LO

The second method was to replace the LO crystal to bring the IF down into the 2 meter range. With a 96 MHz rock, (which I just happened to have laying around; I have an interesting junk box), the IF became 142.5 MHz for 2446.5 MHz in. Measuring IF our level against RF in level showed no detectable difference in conversion gain between 2400 MHz with a 94 MHz crystal and 2445 MHz with the 96 MHz crystal. And I didn't even have to re-peak the LO trimmer. Once again, increasing RF frequency showed this to be near the edge of the filter passband. Conversion level was 20 db down at 2485 MHz and 40 db down at 2500 MHz. The slightly steeper dropoff experienced with the first test (with a 190 MHz IF) is expected since the converter uses a 5/4 wavelength ring mixer, which is frequency specific and would be expected to offer some attenuation when used away from its design (146 MHz) frequency.

Antennas

Loop yagis, commonly used for S band downlinks, are noted to have low pass filter characteristics. While I do not have Down East Microwave loop yagis, I do have a homebrew 52 element loop yagi cut for 2390 MHz and adjusted for best return loss at 2401 MHz. It proved to be 3-4 db down at 2446 MHz and fell off quite rapidly above that. Since ARSENE is a low orbit satellite, this antenna will be satisfactory. Since DEM's loop yagis for satellite use are cut specifically for 2400 MHz, I would expect their performance to be similar.

Preamps

The common WB5LUA no-tune GaAsFET preamp is quite broad and falls off only slightly at 2446. No problem.

Conclusion

The DEM S band downconverters appear suitable for receiving ARSENE on 2446 MHz. While the preferred method of modification is to change the LO crystal, simply using a general coverage receiver to tune a 190 MHz IF should provide satisfactory performance.

Test Methods

While my test methods are not exactly traceable to any standards, they do provide relative accuracy (verified by comparison to fixed attenuators) and have proven to be repeatable. The method used to test the converter was to supply a low level RF signal from a TS403A/U (equivalent to the HP616A) UHF signal generator, and watch the converter's IF output level on a homebrew TV-tuner spectrum analyzer. Fixed high quality attenuators were inserted at the converter's input and output to insure 50 ohm loads to the converter. The RF input level was varied to maintain a fixed IF output level as the frequency was varied. The IF level and frequency were compared on the spectrum analyzer display to a reference signal from an HP608E VHF signal generator.

Antenna testing was done indoors. The antenna was peaked on a signal source supplied by a (tiny) ground plane antenna. Then source level was varied as the frequency was changed to maintain a constant power level on a sensitive homebrew power meter attached to the loop yagi. No filters were used between the antenna and the power meter to insure that I was reading the antenna, not the filter. While the 20 foot separation of the source and the loop yagi may seem too close for reliable readings, use of very low power levels (less than -10 dbm or .1 milliwatt) on the source antenna and the short wavelength make readings fairly repeatable. ■

Satellite Orbital Elements

By Dick Campbell, N3FKV

Satellite	AO-10	UO-11	RS-10/11	AO-13	FO-20	AO-21	RS-12/13
Catalog Number	14129	14781	18129	19216	20480	21087	21089
Epoch Time	93049.63647051	93046.09611398	93048.72858228	93045.46345107	93044.20455127	93048.73918589	93043.01588136
Element Set	0969	400	556	563	438	701	393
Inclination	027.0170	97.8238	82.9281	57.6475	99.0594	82.9445	82.9213
RA of node	039.3347	77.8331	326.9109	332.9272	283.7688	141.2286	14.9359
Eccentricity	0.5996940	0.0012964	0.0010904	0.7262121	0.0540939	0.0035815	0.0030957
Arg of Perigee	059.0327	31.5913	295.6648	308.3679	7.5528	356.7600	33.2578
Mean Anomaly	346.4198	328.6069	64.3373	6.4386	353.3323	3.3311	327.0513
Mean Motion	02.05878389	14.68858390	13.72308611	2.09722755	12.83217568	13.74509449	13.74014278
Decay Rate	.00000000	5.49e-06	9.7e-07	-6.2e-07	1.7e-07	1.01e-06	8.5e-07
Epoch Rev	7282	47879	28346	3578	14141	10303	10133
Checksum	320	345	328	316	307	284	291
Satellite	AO-16	DO-17	WO-18	LO-19	UO-22	KO-23	MIR
Catalog Number	20439	20440	20441	20442	21575	22079	16609
Epoch Time	93046.10058181	93043.72242124	93035.22338149	93046.07887758	93040.24894820	93006.08586143	93050.08727348
Element Set	544	546	547	545	243	86	0888
Inclination	98.6313	98.6309	98.6311	98.6319	98.4864	66.0809	051.6227
RA of node	132.4918	130.3095	121.9214	132.8348	118.3602	303.5860	092.5136
Eccentricity	0.0011058	0.0011191	0.0011597	0.0012282	0.0007834	0.0013347	0.0002589
Arg of Perigee	180.0793	188.0644	215.3259	180.8662	324.9777	229.3565	017.2740
Mean Anomaly	180.0392	172.0363	144.7153	179.2508	35.0893	130.6278	342.8973
Mean Motion	14.29795854	14.29927437	14.29908715	14.30000338	14.36774641	12.86275910	15.58954964
Decay Rate	1.95e-06	1.92e-06	2.33e-06	2.03e-06	2.25e-06	-.00000000	2.0193e-04
Epoch Rev	15999	15966	15845	16001	8229	1899	40071
Checksum	320	295	298	296	318	293	322

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 Digital Modes _____
 Gateway Ops. _____

VHF/UHF operation:

SSB/CW _____
 EME _____
 FM _____
 ATV _____
 Packet _____
 Other _____

HF Operation:

Ragchewing _____
 Nets _____
 DX _____
 Packet _____

Design & Construction:

Antennas _____
 Accessories _____
 Test eqpt. _____
 Transceivers _____
 VHF/UHF eqpt. _____

SSTV _____
 QRP _____
 Other(s) _____

m.wave eqpt. _____
 Other(s) _____

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 Other(s) _____

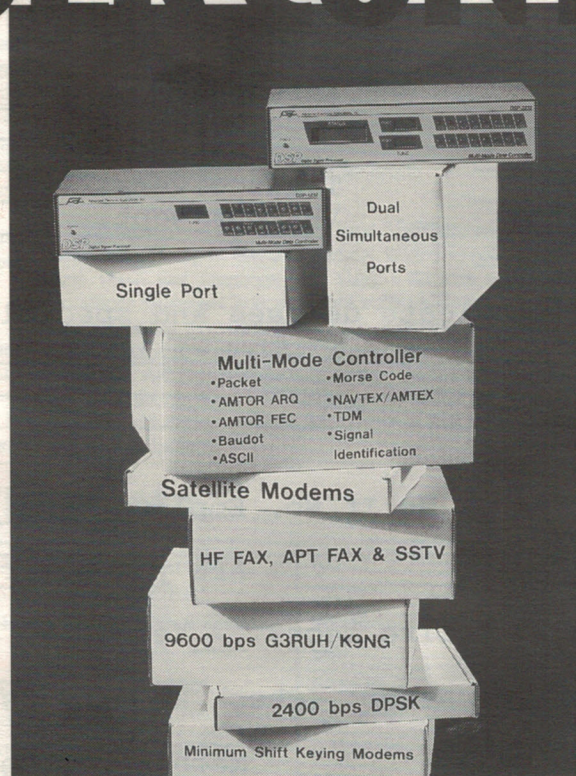
Can your company perform tests (RFI, Thermal/Vac, Vibration, etc.) on modules or complete (large) spacecraft? ___ Yes ___ No If Yes, please provide details on facilities possibly available. (Use a separate sheet to provide this information or to elaborate on any of your responses.)

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